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PROJECT
Contemporary
Historical
Examination of
Current
Operations
REPORT

IMPACT OF GEOGRAPHY ON AIR OPERATIONS IN SEA (U)

11 JUNE 1970

HQ PACAF

Directorate, Tactical Evaluation
CHECO Division

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14. ABSTRACT

Project CHECO was established in 1962 to document and analyze air operations in Southeast Asia. Over the years the meaning of the acronym changed several times to reflect the escalation of operations: Current Historical Evaluation of Counterinsurgency Operations, Contemporary Historical Evaluation of Combat Operations and Contemporary Historical Examination of Current Operations. Project CHECO and other U. S. Air Force Historical study programs provided the Air Force with timely and lasting corporate insights into operational, conceptual and doctrinal lessons from the war in SEA.

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DEPARTMENT OF THE AIR FORCE
HEADQUARTERS PACIFIC AIR FORCES
APO SAN FRANCISCO 96553

OFFICE OF THE CHIEF OF STAFF

PROJECT CHECO REPORTS

The counterinsurgency and unconventional warfare environment of Southeast Asia has resulted in the employment of USAF airpower to meet a multitude of requirements. The varied applications of airpower have involved the full spectrum of USAF aerospace vehicles, support equipment, and manpower. As a result, there has been an accumulation of operational data and experiences that, as a priority, must be collected, documented, and analyzed as to current and future impact upon USAF policies, concepts, and doctrine.

Fortunately, the value of collecting and documenting our SEA experiences was recognized at an early date. In 1962, Hq USAF directed CINCPACAF to establish an activity that would be primarily responsive to Air Staff requirements and direction, and would provide timely and analytical studies of USAF combat operations in SEA.

Project CHECO, an acronym for Contemporary Historical Examination of Current Operations, was established to meet this Air Staff requirement. Managed by Hq PACAF, with elements at Hq 7AF and 7AF/13AF, Project CHECO provides a scholarly, "on-going" historical examination, documentation, and reporting on USAF policies, concepts, and doctrine in PACOM. This CHECO report is part of the overall documentation and examination which is being accomplished. Along with the other CHECO publications, this is an authentic source for an assessment of the effectiveness of USAF airpower in PACOM.

ROLAND A. CAMPBELL, Major General, USAF
Chief of Staff

DEPARTMENT OF THE AIR FORCE
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REPLY TO ATTN OF: DOVD

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SUBJECT: Project CHECO Report, "Impact of Geography on Air Operations in SEA" (U)

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FOR THE COMMANDER IN CHIEF

Maurice L. Griffith

MAURICE L. GRIFFITH, Colonel, USAF
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FOREWORD

Geographic or environmental considerations serve as modifying elements in operational planning and the conduct of military operations.[1/] Accordingly, a strictly geographic approach is one valid way to evaluate the environmental problems of tactical air encountered within an area of conflict. The physical environment in Southeast Asia, although not entirely new to the United States' military experience was sufficiently different to impose limitations on operations. There are, for example, great climatic variations over the Indochinese landmass, because of differences in latitude and the marked variety of relief.

To show its impact on air operations, this CHECO Report reviews the physical geography of Indochina--South Vietnam, North Vietnam, Laos, and Cambodia--in terms of topography, climate, vegetation, and soils. It also describes complexities of the cultural landscape--the natural landscape as changed by man. It is an ecosystem: a complex interaction of living things in relation to environment.

Assessing tactical air employment within the Indochinese ecosystem, "Effects of Geography on Air Operations in SEA," considers problem areas: reconnaissance, airstrikes, search and rescue, as well as a changed environment because of usage of weapons. An appraisal of the effects of climate on flying weather may be found in the Special CHECO Report, "Impact on Darkness and Weather on Air Operations in SEA." Many other studies also detail the climatology of Southeast Asia.[2/]

CHAPTER I

PHYSICAL ENVIRONMENT

Written on the face of Indochina are diverse physical characteristics--variations in topography, climate, and soils which create a patchwork of different landscapes within the larger tropical zone (Fig. 1). Monsoons provide alternating wet and dry seasons, while the huge deposits of mud and silt carried by river systems produce soils of a different nature from those generally found in the tropics. There are small areas which are characterized by the interrelationship of man and animals with the physical features of vegetation, soils, and climate.

Each of these areas presents a singular problem to the military planner, for tactics which are practical in the Delta region may not apply in areas of multi-canopied rain forest. To gain a comprehension of the environment within which air operations are being conducted, geographical elements comprising the entire environment must be understood. Difficulty arises in separating one element from the other, as vegetation is intimately related to climate and soils, and the occurrence of vegetative types found in Indochina must be explained in relation to these prevailing conditions. Although soils, for example, may not directly affect air operations, their impact on both friendly and enemy ground forces is significant. Their effect lies in the indirect impact they have in supporting "friendlies" or in combating enemy forces.[1/]

Climate

The climate of Indochina is monsoonal and subtropical, with high humidity prevailing throughout the year. "Monsoon" means a seasonal shifting of prevailing winds due to a change in the relationship of the barometric pressures between the vast Asiatic landmass and the oceans to the south and east. As with all other places in the northern hemisphere, seasons can also be defined in terms of the relationship of the earth with the sun. Therefore, there is a winter season from December through March as well as spring, summer, and autumn. Because of the nearness of Indochina to the equator, however, these seasons are best described in terms of precipitation rather than temperature. The two major seasons are the northeast and southwest monsoon periods, which correspond generally to winter and summer, respectively. There are also two transitional periods which correspond to spring and autumn.

In winter, the air over the center of Asia becomes cold and dense, creating an area of high pressure. Cool, dry air is subsequently forced toward the warmer, less dense Indian Ocean atmosphere which is at lower pressure. From the prevailing direction of these winter winds, the flow of air is called the northeast monsoon. Conditions reverse in the summer. As the air above the center of the continent warms, it rises, creating a massive low pressure area which attracts air masses from the seas to the south. These air masses contain great quantities of moisture from moving across thousands of miles of ocean.

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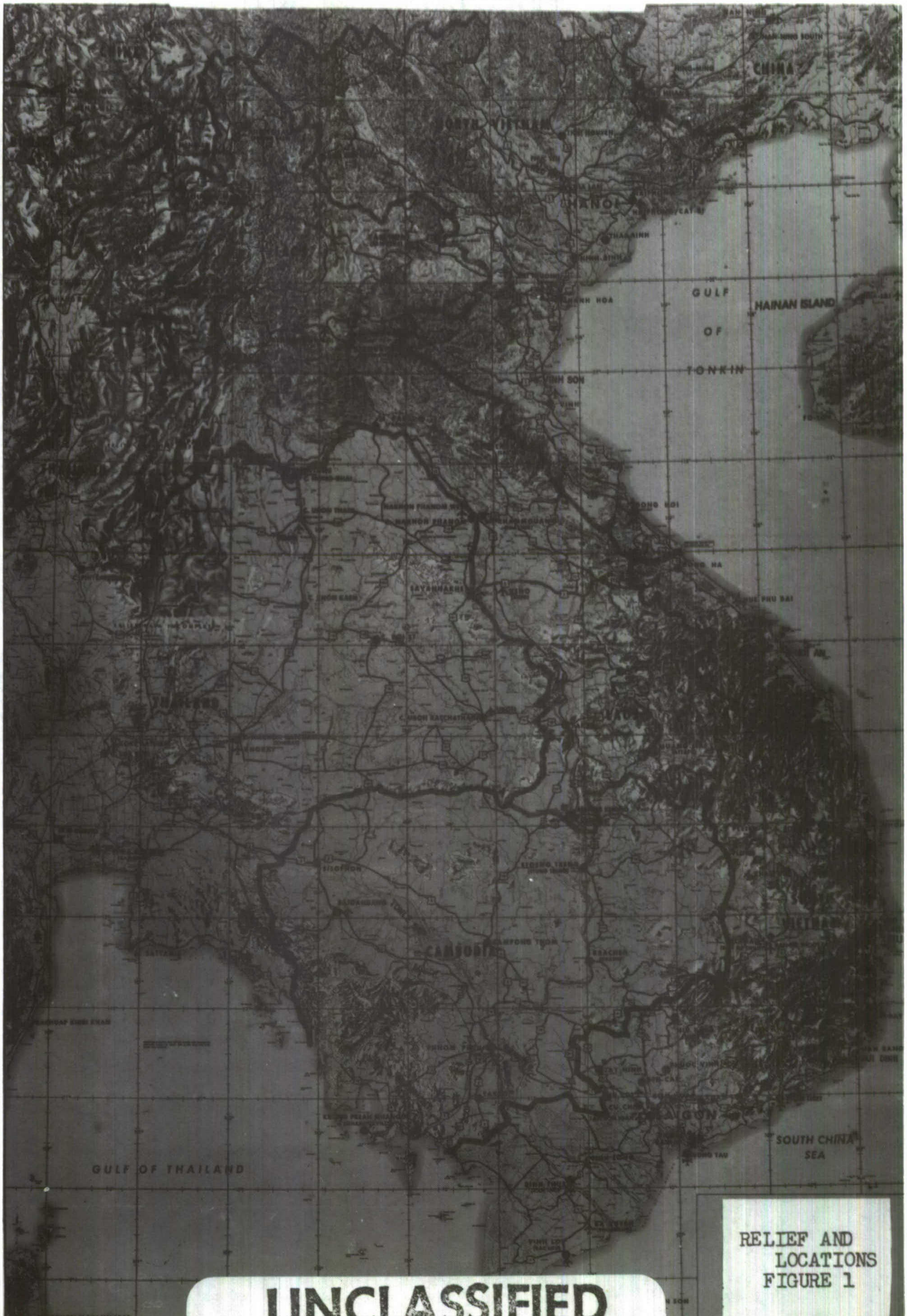

RELIEF AND
LOCATIONS
FIGURE 1

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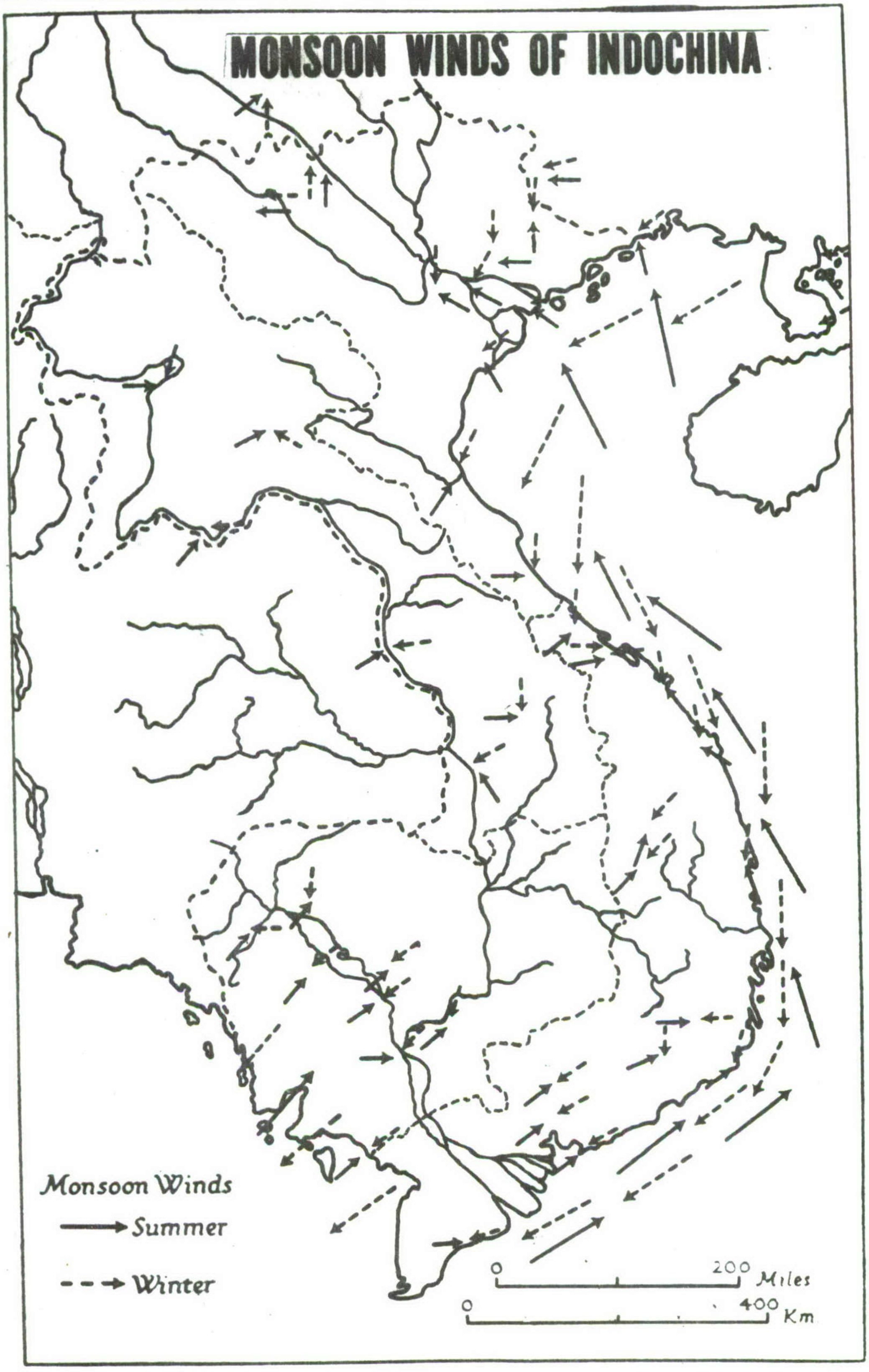


SOURCE: Indo-China

FIGURE 2

Upon reaching the warmer shore, the air is forced to rise, precipitating its moisture. The summer winds are called the southwest monsoon (Fig. 2).[2/]

Precipitation

The southwest monsoon brings the highest period of precipitation to Indochina. Yet, it is not a period of continuous rain, rather the rainfall tends to be somewhat cyclical. In the Saigon area, for example, a seven-day scale is used to predict rainfall. On the first two days, no rain is forecast, but beginning on the third day, rain is forecast at about 1800 LST. For each succeeding day, the rain is forecast to begin one and one-half hours earlier until local noon; however, on this day it usually rains all day. After about seven days, this series breaks down and is followed by a few days of clearing before being repeated.

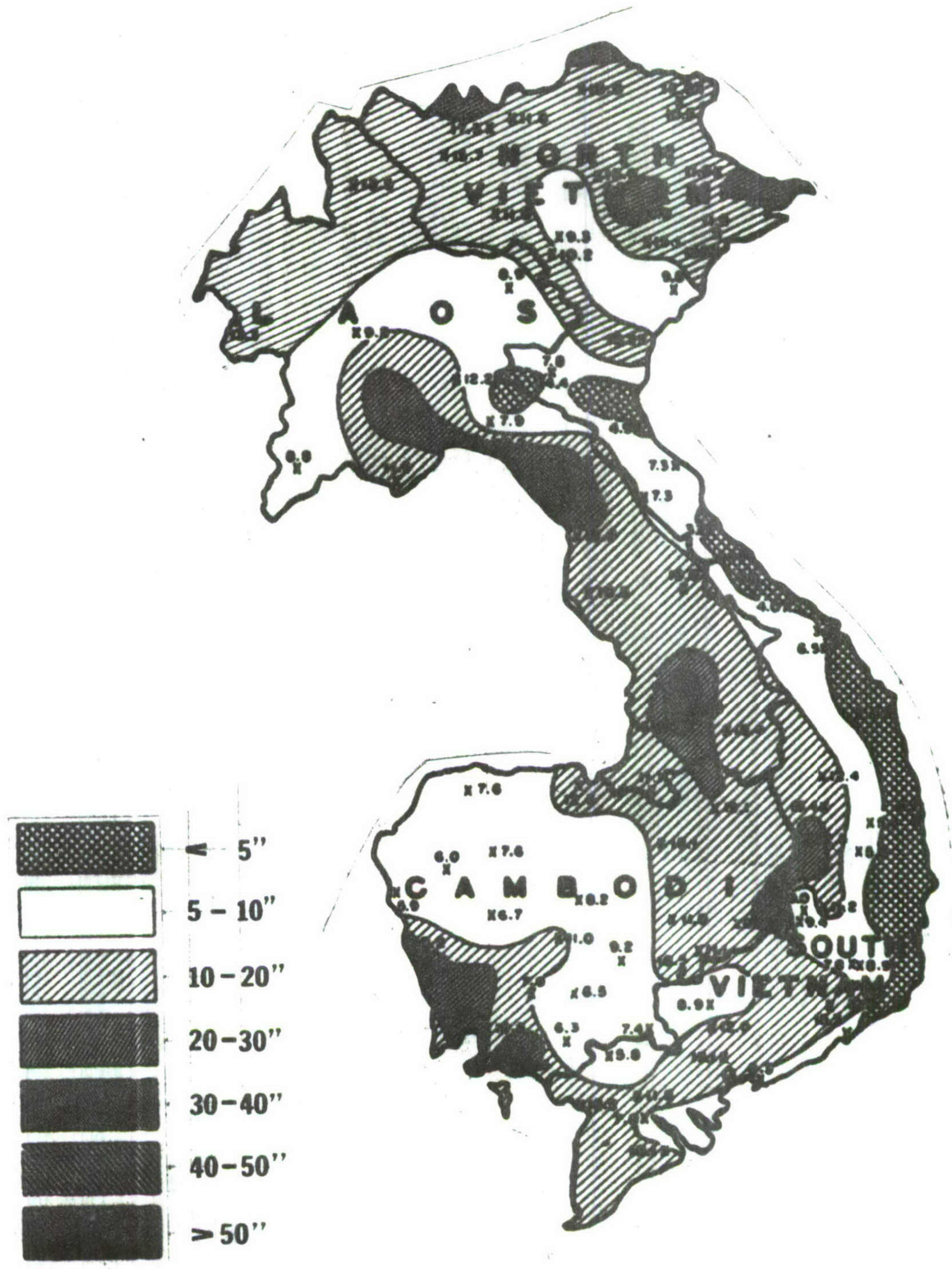
On a larger scale, Figure 3 indicates that rainfall is not evenly distributed across the entire Indochinese area. Cambodia and South Vietnam receive most of their annual precipitation during the southwest monsoon and autumn transition periods from rainshowers and thunderstorms of short duration. The wettest areas are found in the Cardamom, Elephant, and Annamite ranges where the mountains cause the wet winds to rise and drop their moisture. These mountains, in turn, shelter the downwind areas producing less rainfall in the central section of Cambodia and along the Republic of Vietnam coast.

In the northeastern portion of South Vietnam, the greatest precipitation and cloud cover are recorded on the windward slopes of the Annamite

Chain. Pleiku, for example, has a monthly average of 16.4 inches. There is a marked sheltering of the east coast by these mountains, however, as indicated by the 2.1 inches per month recorded at Qui Nhon. The total cloud picture is also noteworthy as there is a daytime average of 25 to 30 percent less broken-to-overcast cloudiness between the mountain area and the dry coastal section. A high percentage of overcast also exists at 0700 LST at Pleiku, due to fog and low stratus that forms briefly near sunrise throughout the mountains in the narrower river valleys. During midday and evening, the higher frequency of overcast at Pleiku is related mostly to cumulus and cumulonimbus clouds, which can reach 45,000 to 50,000 feet in this area.

The average cumulus coverage throughout Cambodia and South Vietnam is scattered-to-broken with bases at 2,500 feet. In areas of light showers, conditions become overcast with bases at 1,500 feet, the visibility lowers to about three miles, and surface winds register gusts to 20 knots. A heavy thunderstorm, with tops averaging 25,000 feet in the Soc Trang area, but 40,000 to 50,000 feet over the northern mountains, will lower these conditions to an indefinite ceiling near 500 feet, combined with half-mile visibility and gusty surface winds, that often reach 40 knots and occasionally 60 knots. A typical daily sequence of cloudiness is:

2300-0400 LST - Clear or scattered cirrus, except along the Mekong where intense thunderstorms of short duration develop during this period.



SUMMER MONSOON: PRECIPITATION OVER INDOCHINA

SOURCE: Schutz

FIGURE 3

0400-0900 LST - Local strati overcast in the narrow river valleys.

0900-1000 LST - Clearest time of the 24-hour period, even along the Mekong.

1000-1400 LST - Scattered cumulus based at 2,000 to 3,000 feet.

1400-2300 LST - Scattered-to-broken and, on rare occasions, overcast cumulus and cumulonimbus, slowly decreasing after 1900 LST.

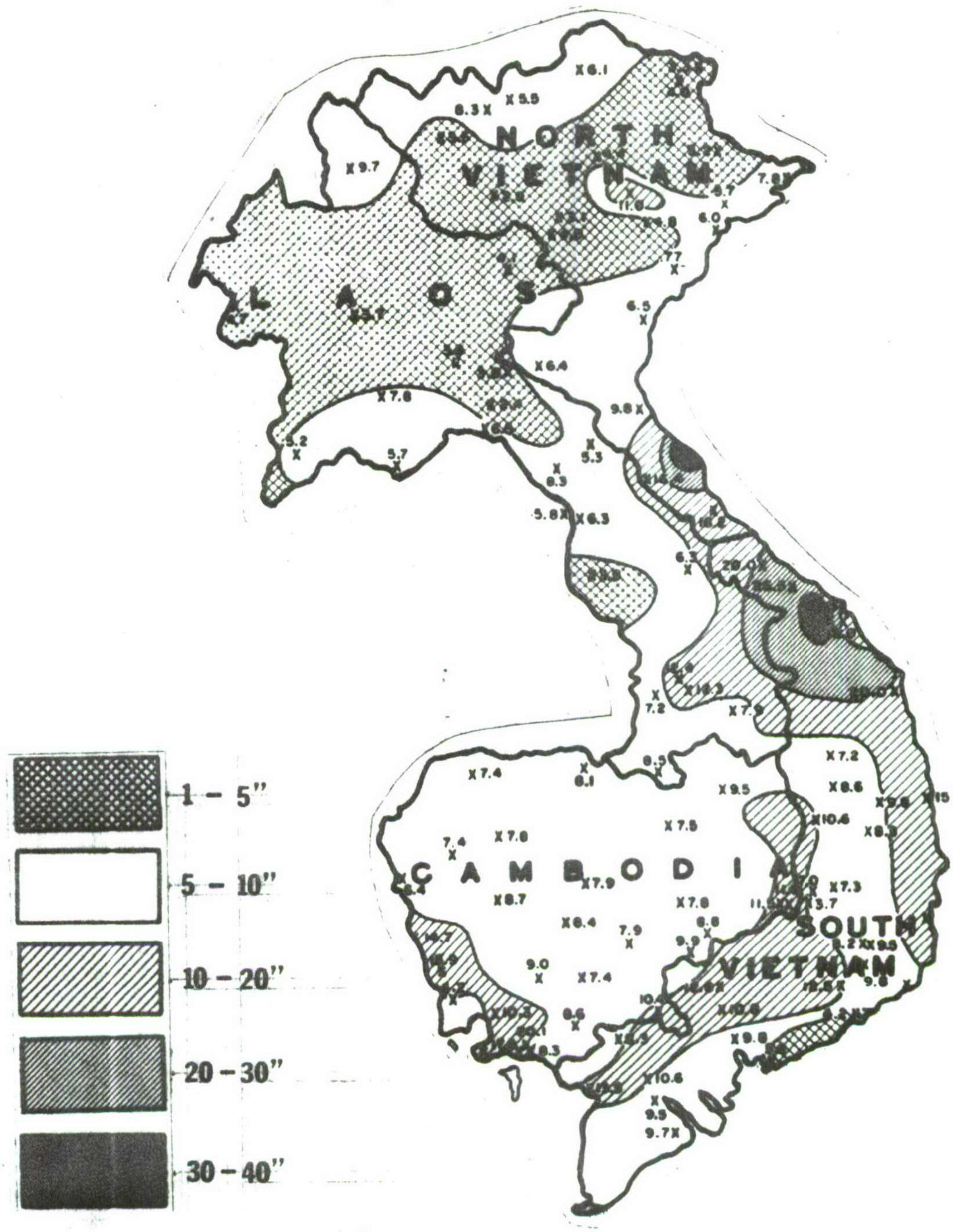
Associated with the southwest monsoon are "the Winds of Laos" which are foehn or chinook type winds. They blow down the eastern slope of the Annamite Chain as hot, dry winds, evaporating moisture and desiccating plants, especially in the coastal lowlands from Nha Trang to Dong Hoi.

The southwest monsoon undergoes considerable change in moisture content and cloud pattern as it moves through Laos and North Vietnam. This is particularly true north of the nineteenth parallel. All semblance of flow is lost along the southern mountain slopes of Laos. In the northern portion of North Vietnam, the flow which continued off-shore to the south is revitalized over the Gulf of Tonkin, as it makes a swing to the northwest and precipitates its moisture. On occasion, there are periods of weather without precipitation but with scattered clouds in northern Laos and northern North Vietnam. Completely clear or cloudless days are unusual, however, but successive days with precip-itation in any given location are also quite rare.

The autumn transition is considered to be the most abrupt because the length of its influence on any given location is the shortest--about one month. Figure 4 illustrates the changes in precipitation pattern which take place. The central Vietnam coast, which was relatively dry during the southwest monsoon, receives the heaviest rain during this period. Convective activity, which is caused by the rising of heated air, is most violent during the transition periods, therefore, most of the rainfall is due to heavy showers and thunderstorms. In the Soc Trang area of South Vietnam, the fall transition is marked by an increase in morning fog and low strati with bases at 800 to 1,200 feet which tend to dissipate by 0900 LST.

Typhoons add much to the fall precipitation totals of coastal Vietnam, from northern South Vietnam through the Northern Delta region. North Vietnam is invaded by typhoons entering the Gulf of Tonkin. The maximum effect occurs in September and October in the southern part of the area. On occasion, typhoons bring increased clouds and precipitation to Laos, but the highly destructive winds are felt only along the eastern slopes of the Annamite Chain.

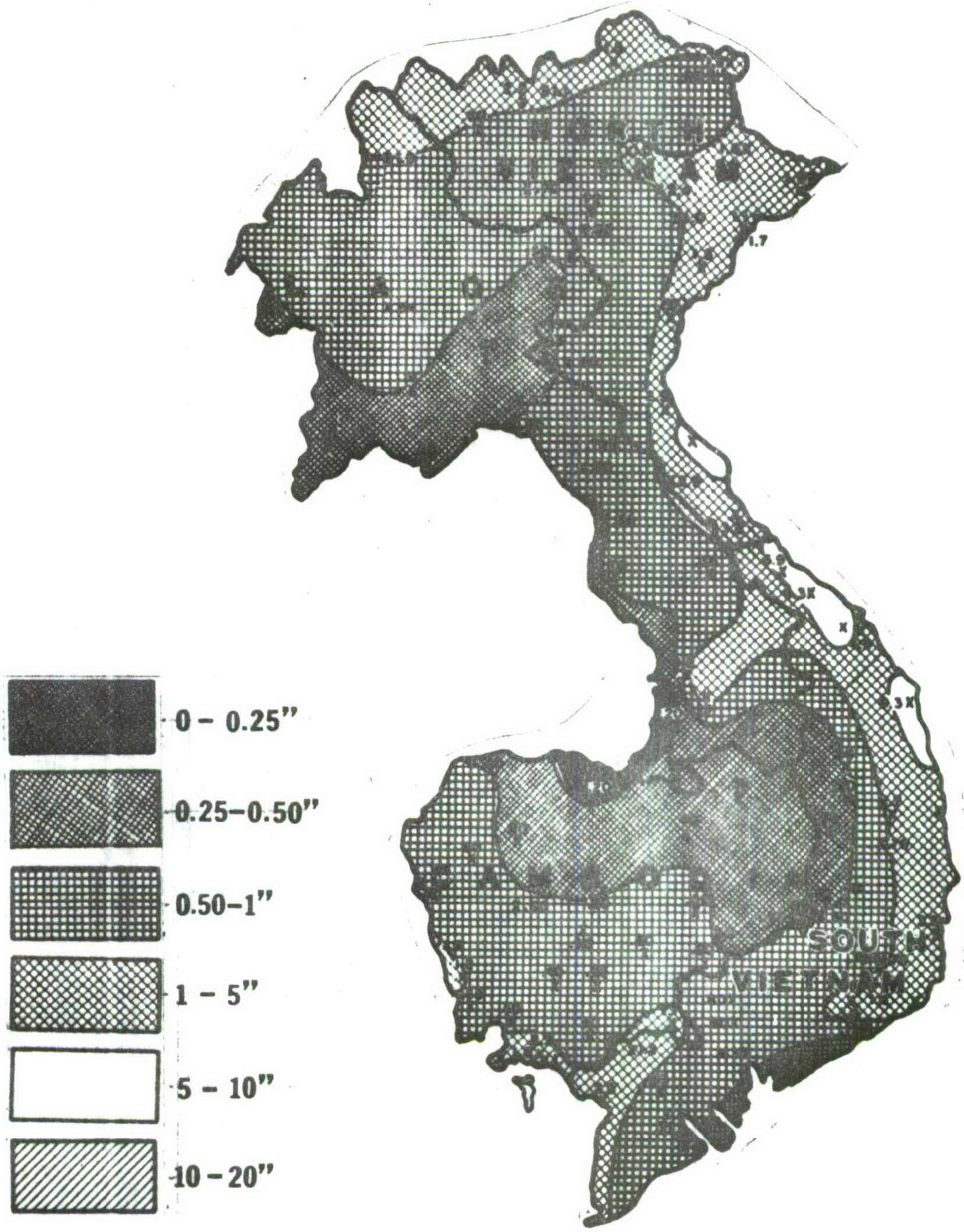
During the winter months, the northeast monsoon is in control over Indochina. Figure 5 shows the precipitation pattern. This northeast flow of air influences the coast of Vietnam south to about 12° north latitude. A concentration of cloudiness known as the "crachin," a prolonged period of widespread fog and drizzle or light rain, is prevalent. The crachin effect is most pronounced near Hanoi, where there is an annual average of 68 days of low ceiling and visibility. The effect of



SOURCE: Schutz

FALL TRANSITION: PRECIPITATION OVER INDOCHINA

FIGURE 4



WINTER MONSOON: PRECIPITATION OVER INDOCHINA

FIGURE 5

this phenomenon decreases to the south. The annual average crachin is 53 days at Hue, 41 days at Da Nang, and only 10 days at Nha Trang. South of the twelfth parallel, there is a minimum of cloudiness during the northeast monsoon.

The clouds that make up the crachin are low-level strati and strato-cumulus with tops rarely above 6,000 feet. These clouds are generally 3,000 to 5,000 feet thick, with ceilings under 1,000 feet, 40 to 50 percent of the time, and frequently below 500 feet, both early and late in the day. Visibility is usually less than two miles and is frequently less than one-half mile.

Laos and Cambodia have similar weather during the northeast monsoon, receiving about ten percent of their annual rainfall during this period. An entire month's rainfall may occur in one or two isolated thunderstorms; completely rain-free months are a common occurrence. Visibilities are usually excellent, with the air crystal clear, except in extreme southern Laos and northern Cambodia. Although this is the clearest time of the year, cloudiness is not completely absent. A normal 24-hour pattern of cloudiness would be:

2300-0400 LST - Clear.

0400-0900 LST - Increasing fog and low strati (1,000 feet or less) over the rivers and in the river valleys.

0900-1000 LST - Usually the clearest period.

1000-1400 LST - Scattered cumulus.

1400-2000 LST - Scattered-to-occasional-broken cumulus with bases 2,000 to 3,000 feet and tops near 8,000 feet.

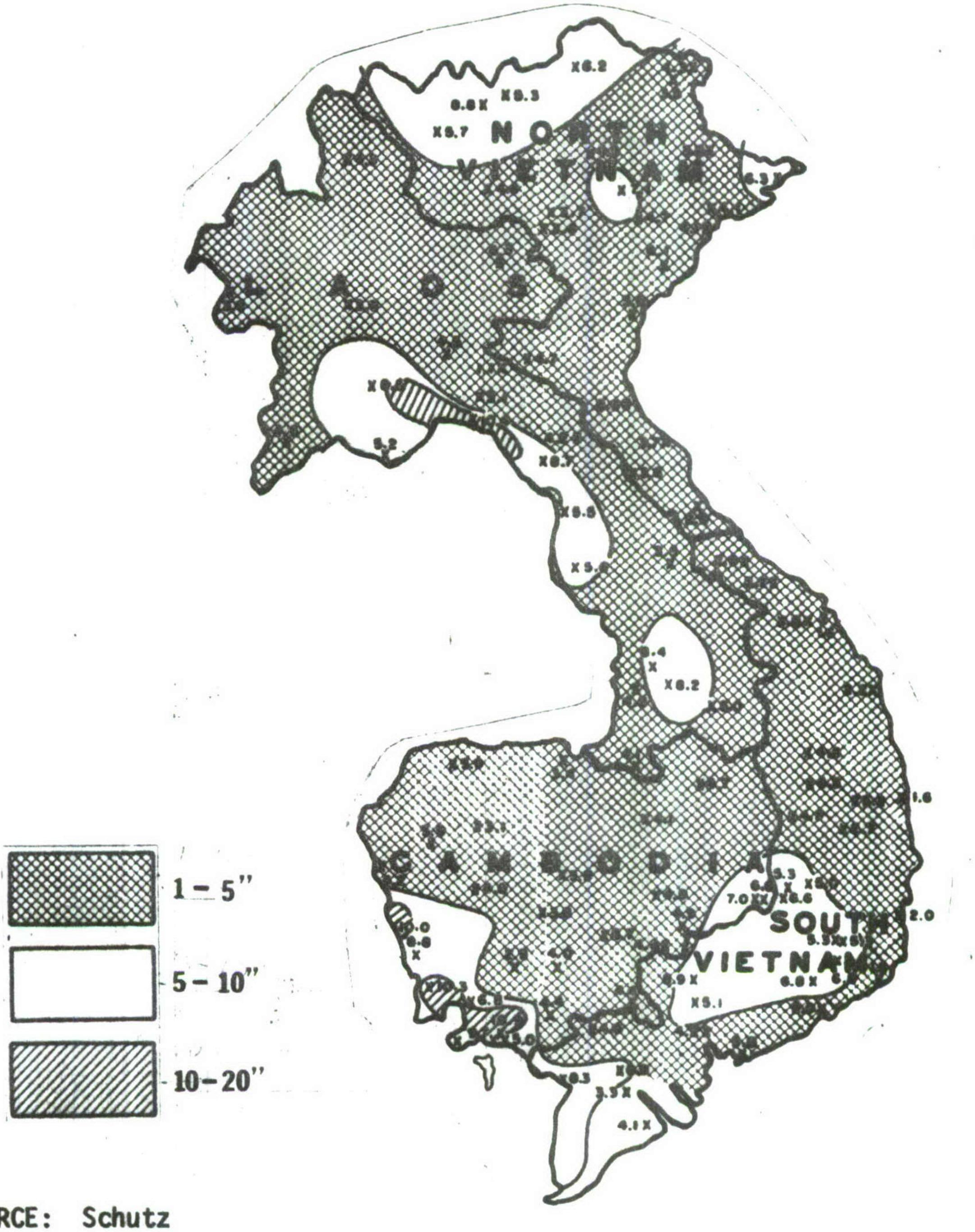
2000-2300 LST - Decreasing cumulus.

There are relatively few cases of broken or overcast cumulus in the evening and thunderstorms are rare at any time of day.

The most persistent cloud cover found in Laos is the frequent fog and low strati which develop in the protected mountain valleys, particularly in the north. This deck generally dissipates between 0900 and noon LST. Excellent examples are Xieng Khouang and Luang Prabang where a normal cloud cover of nearly 75 percent is recorded at 0700 LST. By midday, this cover has decreased to less than 25 percent.

The spring transition is a period of subtle change. Those areas in Indochina where maximum precipitation will occur during the southwest monsoon begin to show a marked increase (Fig. 6). In the Republic of Vietnam, the spring transition can occur anytime between mid-March and early May and is characterized by thunderstorm activity. The spring also brings an end to the crachin along the northern South Vietnamese coast. In North Vietnam, there is an increase in temperature, afternoon clouds, rainshowers, and thunderstorms except through the southern part of coastal North Vietnam where there is a decrease in precipitation.

Conditions also change in Laos. While there are few clouds, there is subtle increase in afternoon thunderstorm activity which tends to be



SOURCE: Schutz

SPRING TRANSITION: PRECIPITATION OVER INDOCHINA

FIGURE 6

ANNUAL TEMPERATURE CURVES FOR SAIGON & HANOI

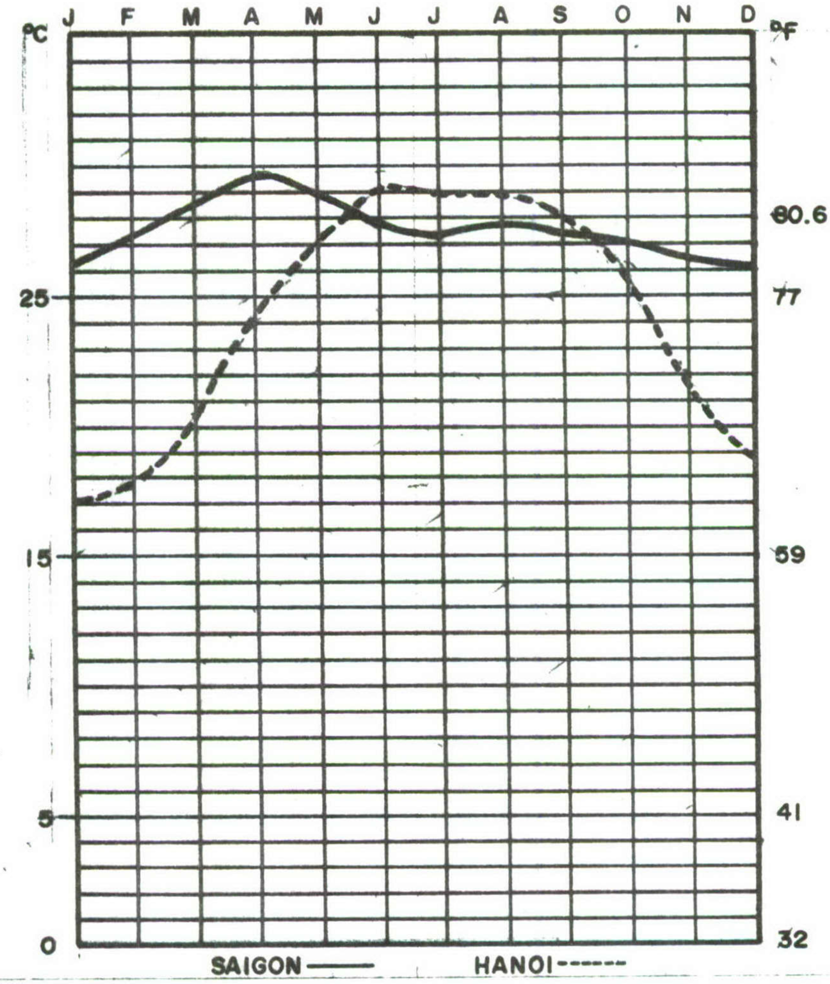


FIGURE 7

very severe with low ceilings, torrential rain, and gale force winds that can last up to two hours. Laos is also characterized by a great increase in haze during March and April.

Temperature

With the exception of the mountainous areas in Indochina, the entire region experiences high temperatures throughout the year. At Hanoi, the coldest month (January) has a mean temperature of 63°F, with the mean annual temperature being 74°F. This differs from the mean annual temperature in Hue (77°F) and Saigon (81°F). Differences in latitude and relief produce two distinctive temperature patterns: one in Saigon, another in Hanoi (Fig. 7).

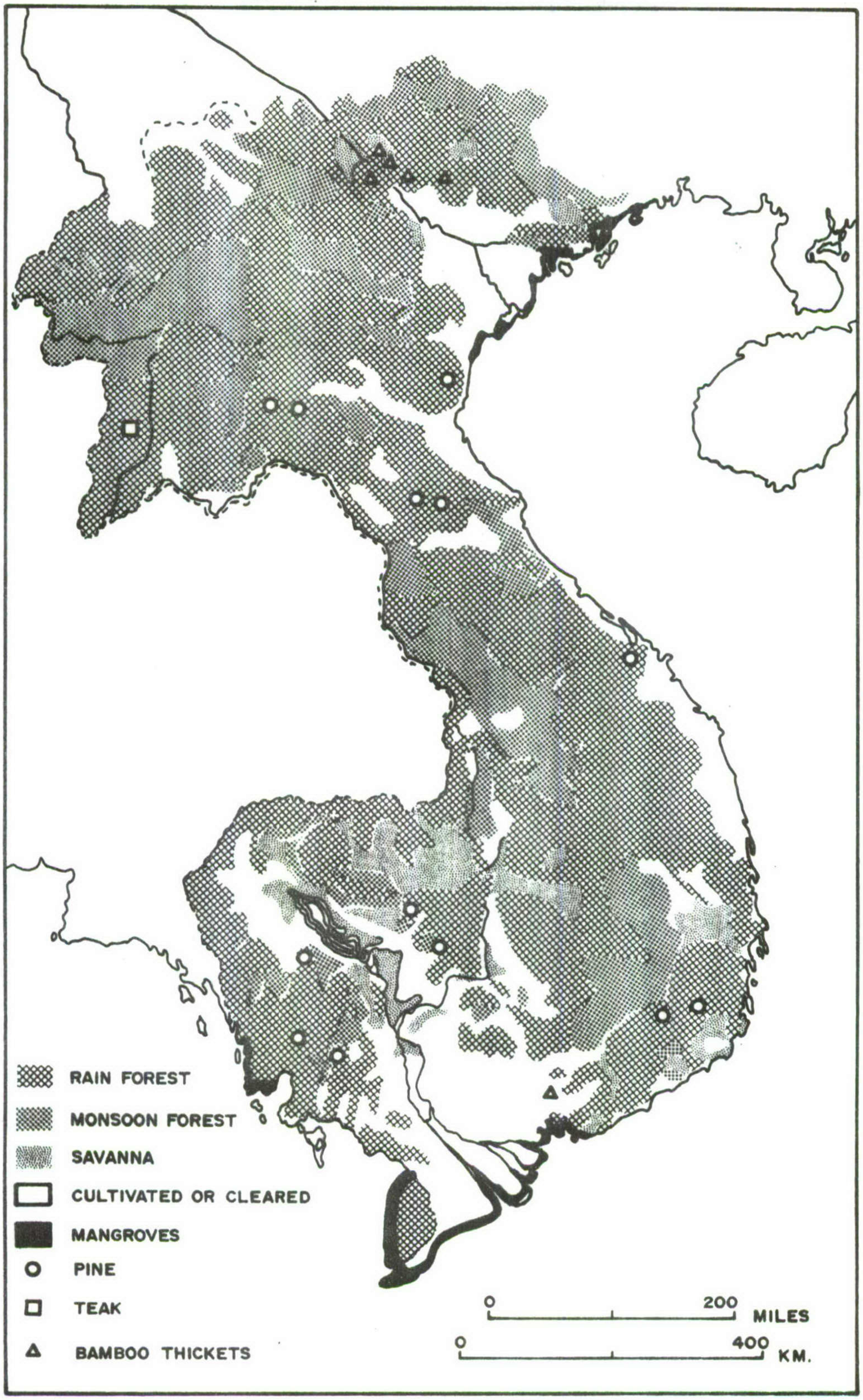
The Saigon pattern extends along the coast of South Vietnam to Nha Trang or Qui Nhon and west of the mountains as far north as Luang Prabang, Laos. Saigon has a small annual range, 6.2°F, with April, the hottest month, having a mean temperature of 85°F and the coldest month, December, 78.8°F. The major distinguishing characteristic, however, is the existence of two annual maximums and minimums, a typical feature of the equatorial climate. Saigon's two maximums occur in April and August; the two minimums in July and December. Diurnal variation is greater in the hottest rather than the coldest month. The daily temperature range averages 21-27°F in April and 18-19°F in December. In both cases, there is a steep rise in temperature from 0600 to 1400 hours, followed by a rapid fall during the late afternoon and evening. Nha Trang has similar temperature conditions, but at Hue this temperature regime does not occur. The double maximums and minimums criteria are met at Luang Prabang, Laos, west of the mountains. Its high annual range of temperature is different due to its interior location.

The Hanoi pattern covers North Vietnam north of Vinh Son. The annual temperature range at Hanoi is greater than at Saigon, averaging 22°F. June is the hottest month and January the coldest. This regime is characterized by single maximum and minimum temperatures. Sharp diurnal changes in temperature are experienced over the whole of northern Indochina. The greatest daily range occurs in winter, which is the reverse of the situation in Saigon. In January, the temperature may fall as much as 32°F in less than ten hours.

In the mountains and plateaus of the Annamite Chain, temperatures are much lower than in the plains to the east and west. Da Lat, for example, located at an elevation of 5,000 feet on the Lang Bian Plateau, has a mean annual temperature of 14°F less than Nha Trang, which lies at sea level in approximately the same latitude.

Temperature variations have significant effects on air operations, particularly in conjunction with the high humidity found in Indochina. High temperatures limit takeoff gross weights for certain types of aircraft. In addition, they have deteriorating effects on various types of ordnance and photographic film which are key components of tactical

VEGETATION IN INDOCHINA



SOURCE: Indo-China

FIGURE 8

air operations.

Vegetation

In its primeval state, Indochina was probably entirely covered with dense forest--about 15 percent of this area has now been cleared. In addition, the forests have been so extensively modified that savanna, or parkland, has been produced in another 45 percent. The remainder, approximately 115,800 square miles, is still covered with dense forest, primarily of secondary origin.

Several different kinds of forest occur, the most significant being: tropical rain, monsoon, pine, and mangroves. The general distribution of these types is shown in Figure 8. Both primary and secondary forests are found in these groups with primary referring to virgin forest, unaltered by man. Secondary forests occur when the primary forest is cleared or partially cleared by felling or burning and allowing the seedlings which spring up to grow into trees. If agricultural land is no longer cultivated, secondary forest will develop.

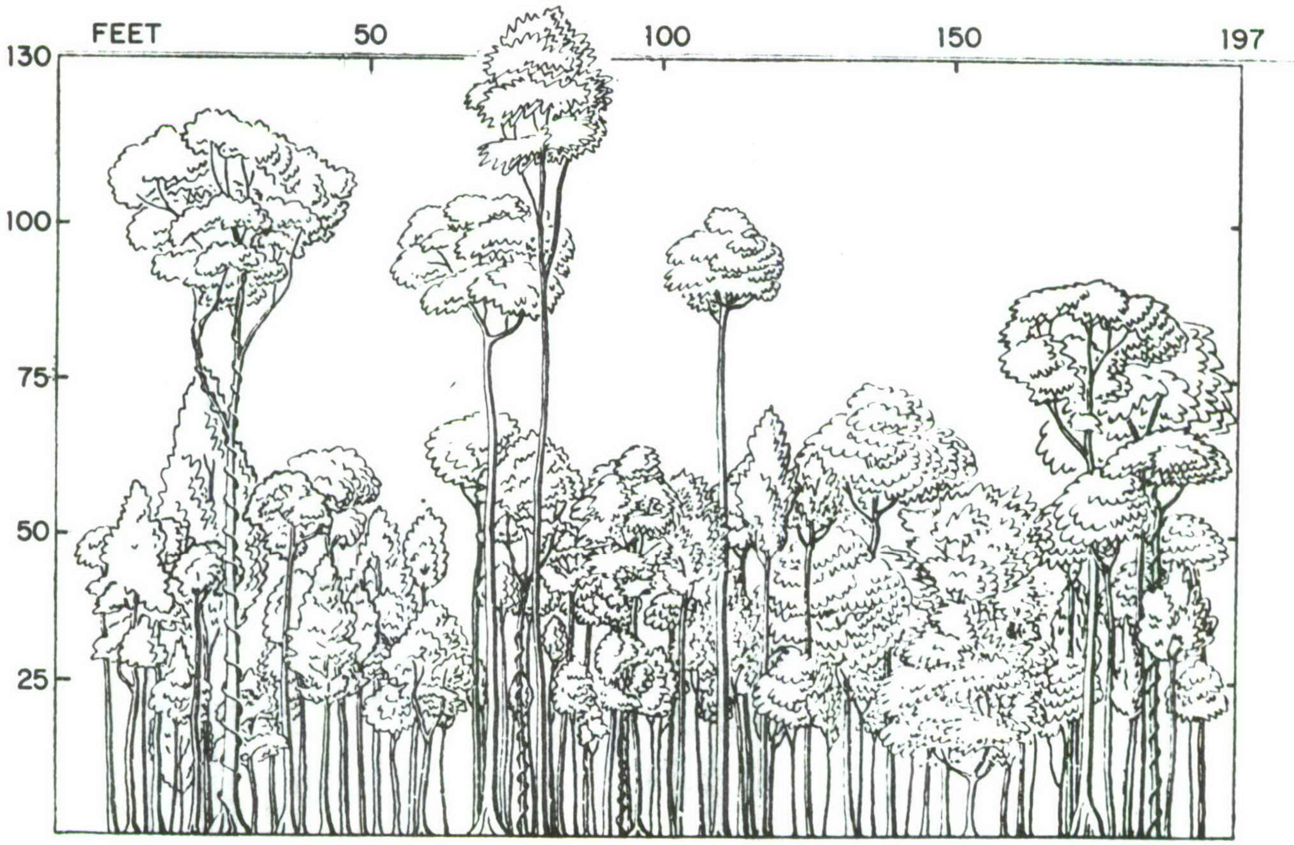
Tropical Rain Forest: This area, consisting of broadleaf evergreen species, occurs in regions with an annual rainfall of more than 80 inches, where the precipitation is fairly evenly distributed throughout the year. In Indochina, it occupies the plains and lower slopes of the mountains up to about 2,300 feet. Local variations in the vegetation are caused by soil. For example, well-drained, light soil may bear monsoon forest even though the precipitation exceeds 80 inches, while evergreen rain forest may occur in regions having less than 80 inches if drainage is impeded.

The average tree height in primary tropical rain forests in Indochina is 80 to 100 feet, although occasional trees may reach 130 or 150 feet and higher. Actually these forests are multi-canopied, containing different levels of trees. The appearance of this type of forest is that of a sea of varying shades of green with scattered crowns of the taller trees standing clear above it. In addition to outstanding and large trees whose crowns form a more or less continuous canopy, there are smaller trees which reach a height of 50 to 65 feet at maturity. Below this canopy, there is usually a fair abundance of seedlings and saplings of various ages and sizes. Figure 9 shows the structure of a typical rain forest.

Because of the continuous canopy shading the floor of the forest, sunlight cannot penetrate, and the floor tends to be somewhat clean. It is relatively easy to walk through the primary rain forest. Owing to the widespread effects of shifting cultivation, or slash-and-burn agriculture, primary rain forest in the region is generally confined to remote or inaccessible places such as the Cardamom Mountains of Cambodia.

The predominant type of rain forest in Indochina is secondary, created in areas where cleared forest land is left uncultivated. The primary forest is replaced in successive stages by secondary growth.

PROFILE OF RAIN FORREST: MATURE TREES



SOURCE: Indo-China

FIGURE 9

SECRET

Secondary Forest in STEEL TIGER Area
in Laos.

FIGURE 10

SECRET

Grassland forms first, followed by shrubs and trees (Fig. 10). Barring repeated fires, grazing, or cultivation, it takes approximately 200 years for a secondary forest to resemble a virgin tropical rain forest.

There are structural differences between primary and secondary forests. Secondary forests have fewer large, tall trees and a greater proportion of shrubs; lower tier vegetation is extremely dense and very difficult to walk through. Forest, with dense undergrowth, is frequently referred to as jungle; however, that is a general term meaning any dense or impenetrable tangle of vegetation.

Monsoon Forest: This type is found primarily in regions which have 60 to 80 inches of precipitation per annum and a dry season which lasts for several months. Usually this forest is more accessible and easier to walk through than rain forest, although there are occasional dense, spiny, impenetrable thickets. Trees found in this formation are deciduous and shed their leaves completely during the dry season. There are frequent fires, particularly in the dry season. If these fires occur annually, only the fire-resistant species will survive; seedlings and saplings are rare. A large part of the undergrowth is made up of tall, coarse grass known as Tranh.

When cleared monsoon forest is abandoned, it goes through a different vegetative sequence from rain forest. Initially, various herbs take over, followed by a dense growth of bamboos and bananas. As time passes, the bamboo thicket may become secondary forest because the shade and protection provided by the dense growth make the habitat suitable for germination of tree seeds.

In the dry season, the trees of the monsoon forest are bare, covering the ground with a brown carpet of leaves. The Tranh turns yellow and the whole forest assumes a yellowish or reddish brown color. The leafless trees bloom about one month before the end of the dry season. When the rains begin, leaves appear with extreme rapidity, the young shoots of Tranh grow rapidly, and the forest again becomes bright green.

Above 2,500 feet, the character of forests change. In some places, pine forest is found, although it, too, may be mixed with, or replaced by, deciduous hardwood trees such as oak. Pine forest is also found in certain lowland areas (Fig. 11).

Mangrove Forests: These are generally found along the coastal flats and marshlands of the Delta regions of Indochina. They can grow in slimy mud and usually form a fairly narrow belt which is very difficult to walk through. As a general term, mangrove includes a great variety of different families of plants. They have a tolerance for salt and fresh water and therefore thrive even in areas of tidal activity. Mangroves may grow to a height of 100 feet.

Savanna Vegetation: This plant life is generally found in regions suited to the monsoon forest. It usually results from disruption of the natural vegetation by man through annual burning or from certain soil conditions inconducive to tree growth. Tranh is the principal

TYPICAL MOUNTAIN VEGETATION IN SOUTHEAST ASIA

(UNEXPLOITED BY SLASH/ BURN AGRICULTURE)

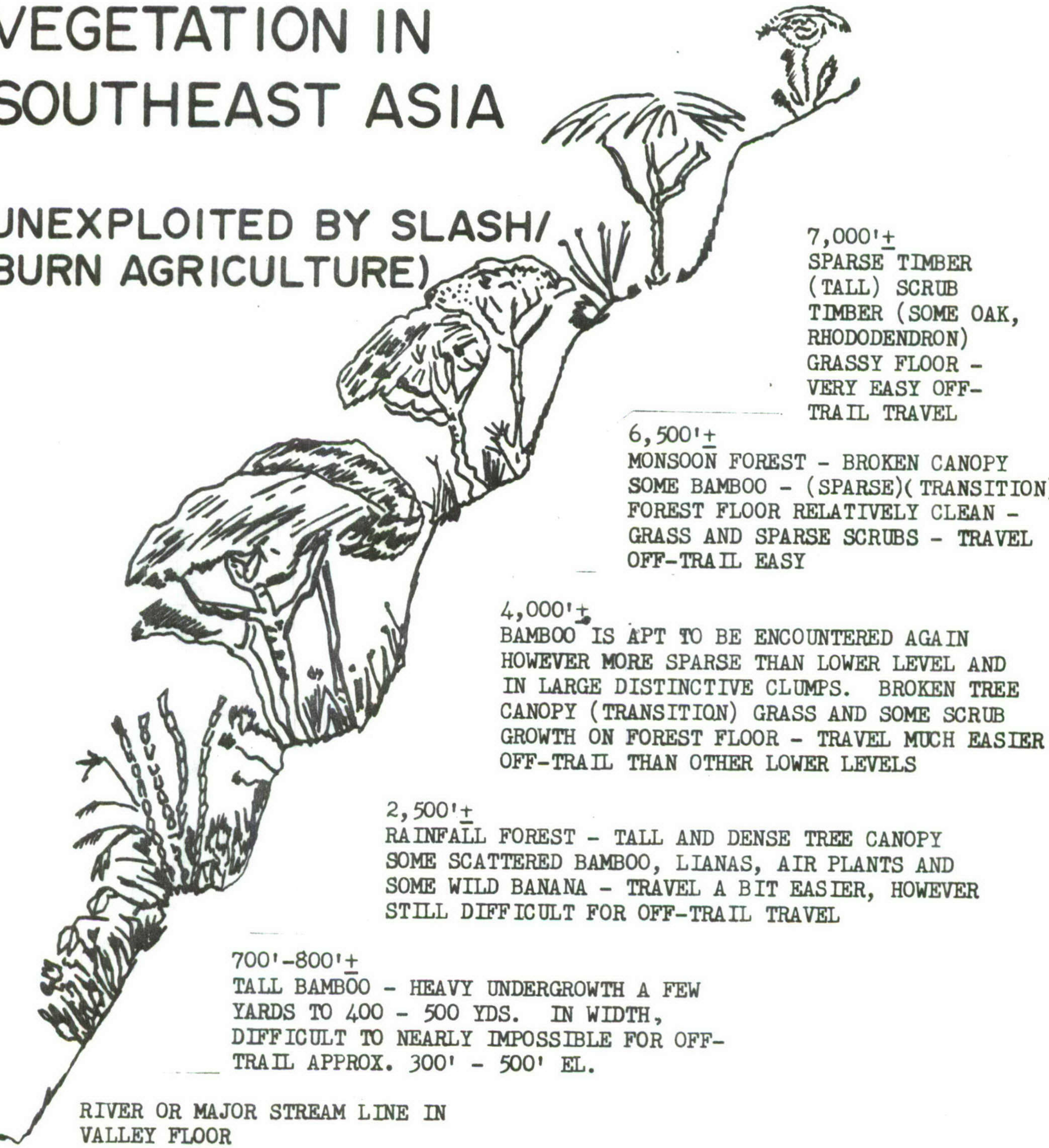


FIGURE 11

non-woody form found in this grassland formation, however, several varieties of shrubs and trees may also be present.[3/]

Soils

The principal factor influencing soil formation in Indochina is climate. Since the annual rainfall greatly exceeds evaporation in most of the landmass, there is a downward percolation of water which leaches the soluble bases from the soil. The amount of organic matter (humus) in the soil determines the order in which the bases are removed. In a tropical climate, very little humus is found despite the luxuriant plant growth. The ever-present high temperatures rapidly break down plant remains; therefore, the floors of the forests tend to be clean. Water containing little or no humus dissolves silica more easily than alumina and iron oxides. This process is called laterization; lateritic soils when fully formed consist of alumina and iron oxides. When laterization is immature, the soil may be very fertile, the degree of fertility generally depending on the parent material of the soil.

Forest cover retards the laterization process. When land is cleared for cultivation, there may be good crops for a few seasons, but minerals in the unprotected land are rapidly leached out of the soil, transforming it into unproductive land. Thus, many native farmers practice shifting agriculture. There are destructive effects with this form of agriculture because clearing of the forest also lays the soil open to surface erosion which is particularly active in high precipitation areas.

The important agricultural lands in Indochina are composed of soils deposited by the many rivers on their flood plains and deltas. The deltas in North Vietnam are built up of soils composed of sand, loam, and clay. All of these delta soils lose fertility due to leaching, but flooding the rice fields retards laterization. In the Mekong Delta region, the most fertile areas extend along both banks of the Mekong. They consist of recent deposits which are rich in nitrogen and potassium but poor in lime and phosphorus. By contrast, the older river deposits near Saigon are extremely poor.[4/]

Physiographic Regions

Generally, Indochina may be divided into eight physiographic regions (Fig. 12), each of which has distinctive physical characteristics:[5/]

North Tonkin Uplands Region

This area, bounded on the southwest by the Red River, consists of complex mountains interspersed with valleys. It includes the northeastern portion of Route Package (RP) 5 and sections of RP-6A and RP-6B. In its southeastern section, the area has relatively low, broken topography, with easy access to the Chinese Border. Vegetation consists of rain forest and savanna grass with large deforested areas and mangroves on the coast. Certain areas of karst topography prevail in the Bac Son, a large limestone plateau located near Lang Son (Fig. 13), with rivers usually running northwest-southeast.

Karst topography is the result of the erosion of limestone formations

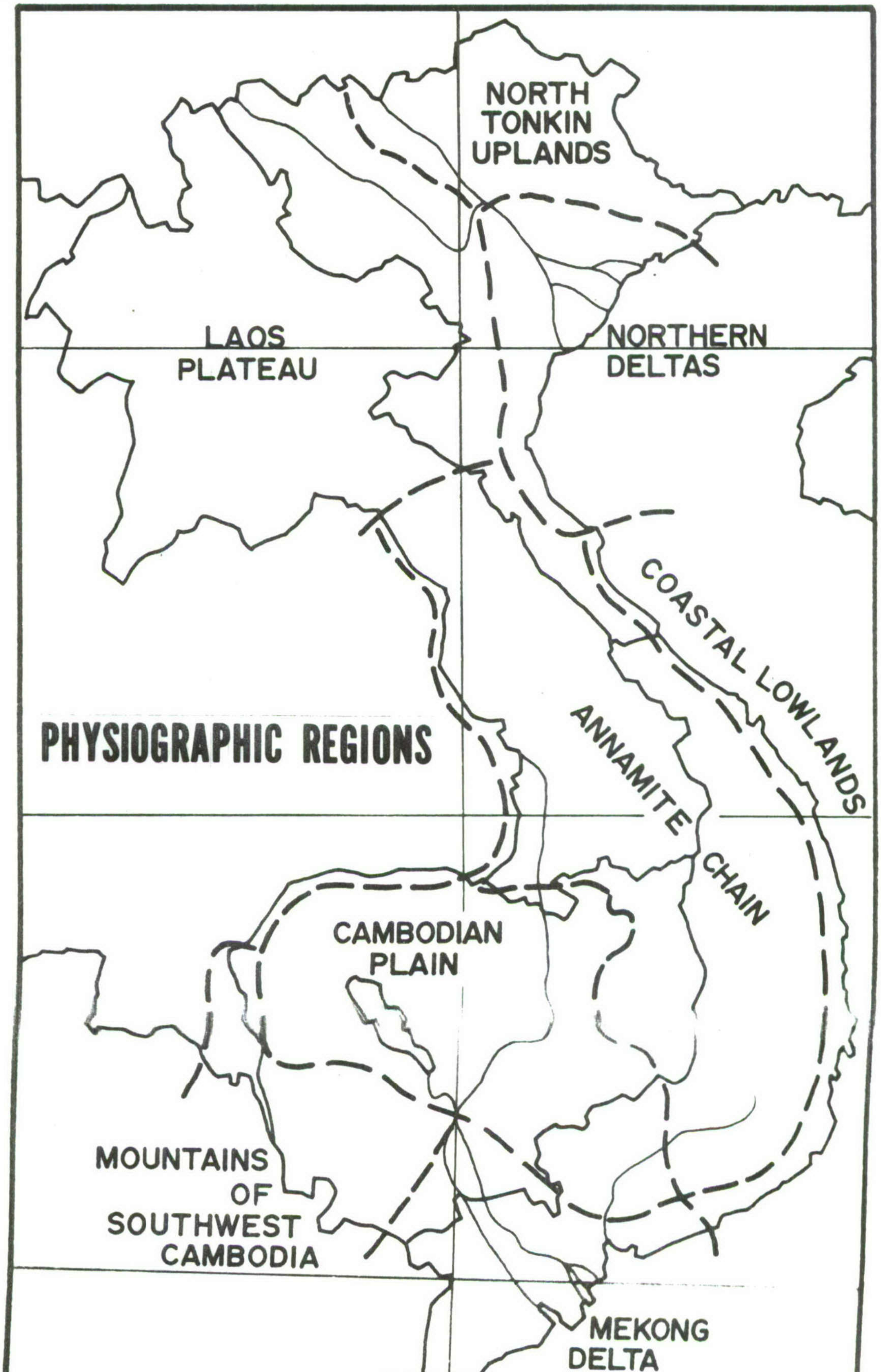
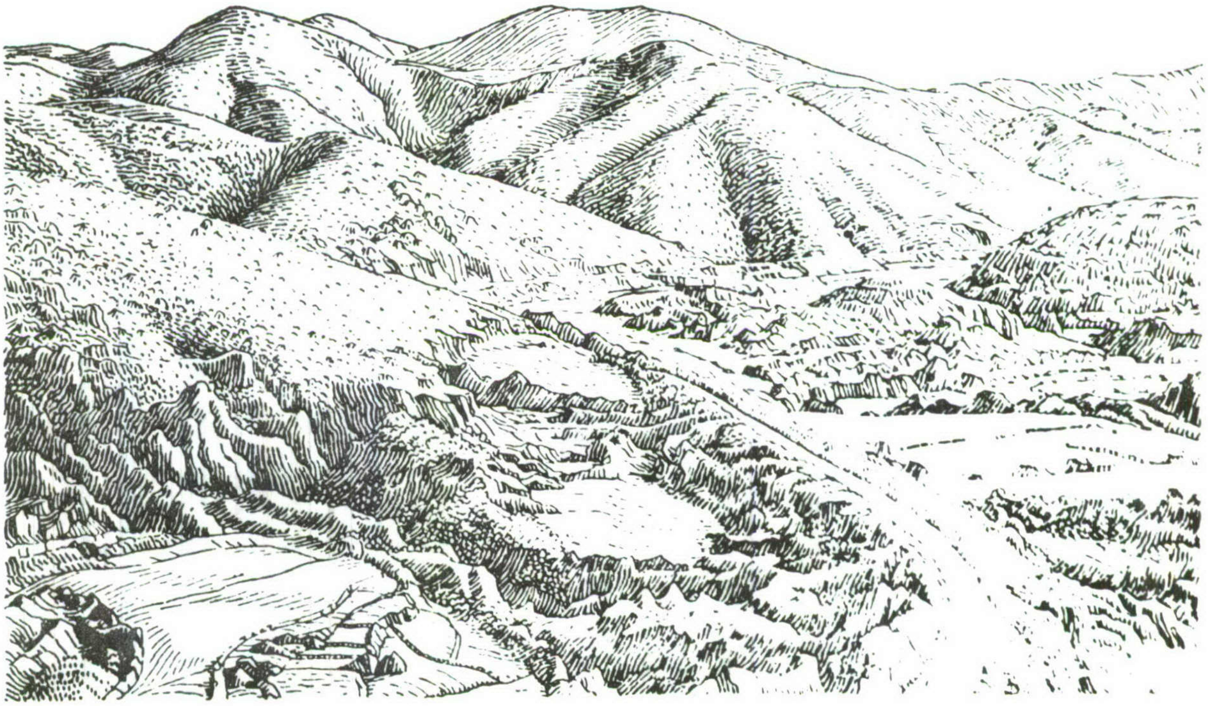

NORTH TONKIN UPLANDS
LAOS PLATEAU
NORTHERN DELTAS
COASTAL LOWLANDS
PHYSIOGRAPHIC REGIONS
ANNAMITE CHAIN
CAMBODIAN PLAIN
MOUNTAINS OF SOUTHWEST CAMBODIA
MEKONG DELTA

FIGURE 12

COUNTRY NORTH OF LANG SON



SOURCE: Indo-China

FIGURE 13

UNCLASSIFIED

by water, and generally consists of large, deep depressions called solution basins, disappearing rivers, caves, and a few rugged hills. As the term has been used in Southeast Asia, it may be defined as limestone formations, usually standing alone with steeply rounded or vertical sides. They are normally honeycombed with caves of various sizes and frequently have a thin layer of vegetation on the top.

The northern portion of the region, Route Packages 5 and 6A, is characterized by rugged chains of mountains, which are an extension of the Yunnan Plateau of China. Rugged peaks contrast with level plateaus, fertile depressions, and deep valleys. The Binh Lang Plateau, rising near the Chinese frontier, is sparsely populated and very difficult to reach, as there are several rocky summits, usually wooded, which reach more than 5,000 feet in height. Solution basins and caves are common features in this limestone area with vegetation consisting principally of rain and monsoon forests.

Laos Plateau

The Laos Plateau includes the extensive mountainous area between the Red River and the Mekong. It coincides with BARREL ROLL and parts of Route Packages 3 and 4. The average elevation is well above 1,600 feet and in many areas above 3,000 feet. Two mountain trends dominate the relief--one northwest-southeast in the eastern portion, the other northeast-southwest in the upper Mekong Basin. With few exceptions, the rivers flow along narrow valleys 2,000 to 4,000 feet deep. The entire mountainous region is generally infertile, little cultivated, and sparsely populated. It, too, has vegetation consisting of rain and monsoon forests (Fig. 14).

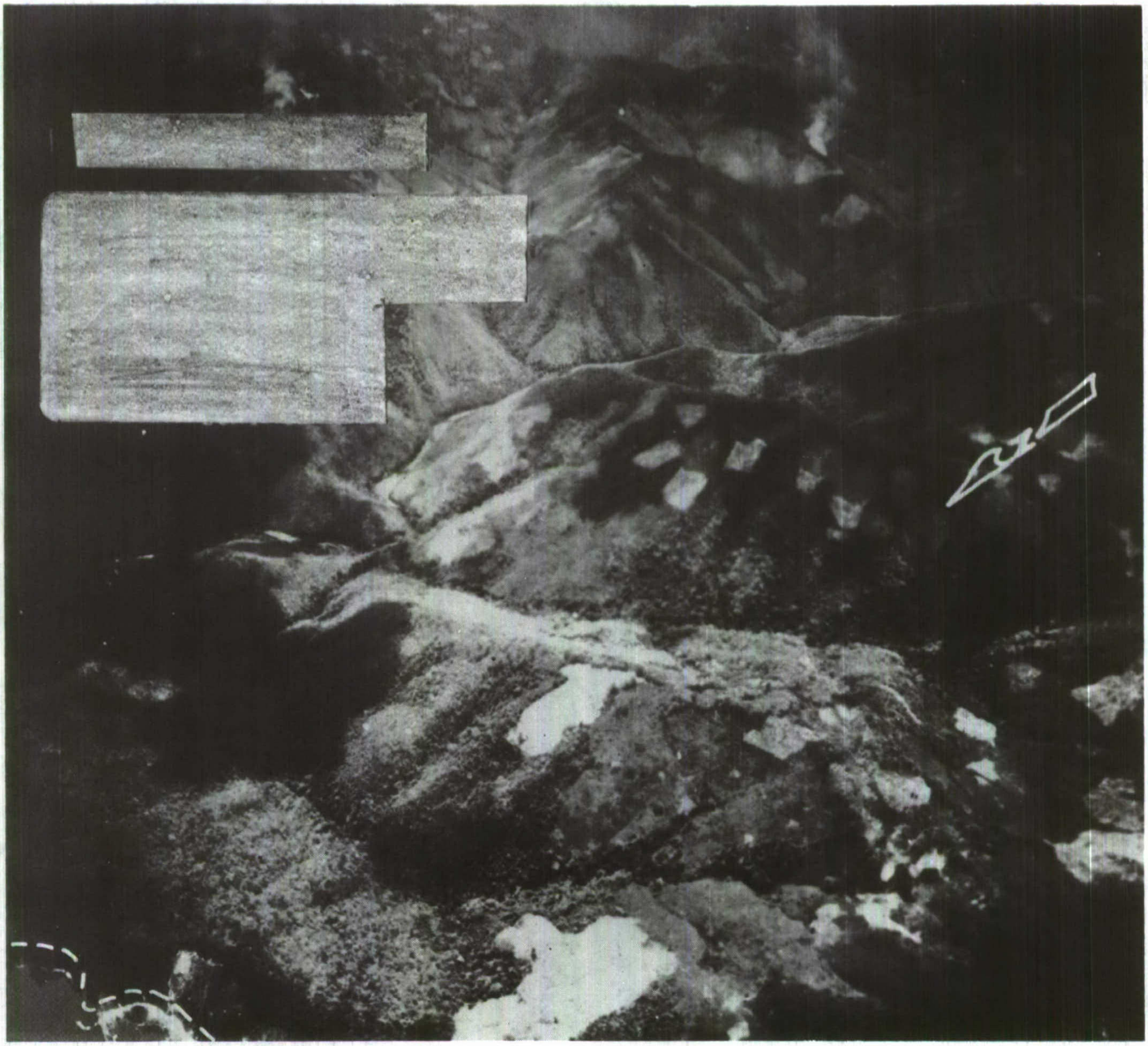
Northern Delta Region

This flat area covers the southern part of RP-6B and the eastern half of RP-4; although smaller, it is more intensively developed by man than the Mekong Delta to the south. The Delta of the Red River extends about 150 miles inland and 75 miles south of Haiphong along the coast. Built up primarily of river deposits, this area was originally an extension of the Gulf of Tonkin, which was filled in by rivers running into the basin.

The Red River rises in Yunnan Province of China with a total length of about 725 miles. Its two major tributaries are the Clear River (Song Ho) and the Black River, giving it a large flow of water--as much as 800,000 cubic feet per second during the rainy season, or twice the maximum flow of the Nile River.

Backed by steep rises of the forested highland, the entire Delta region has only minor variations in relief; most of it is no more than ten feet above the surrounding countryside (Fig. 15). Nearly all the land is cleared for intensive agriculture, but mangroves grow on the coastal fringes and extend some 75 miles to the south.

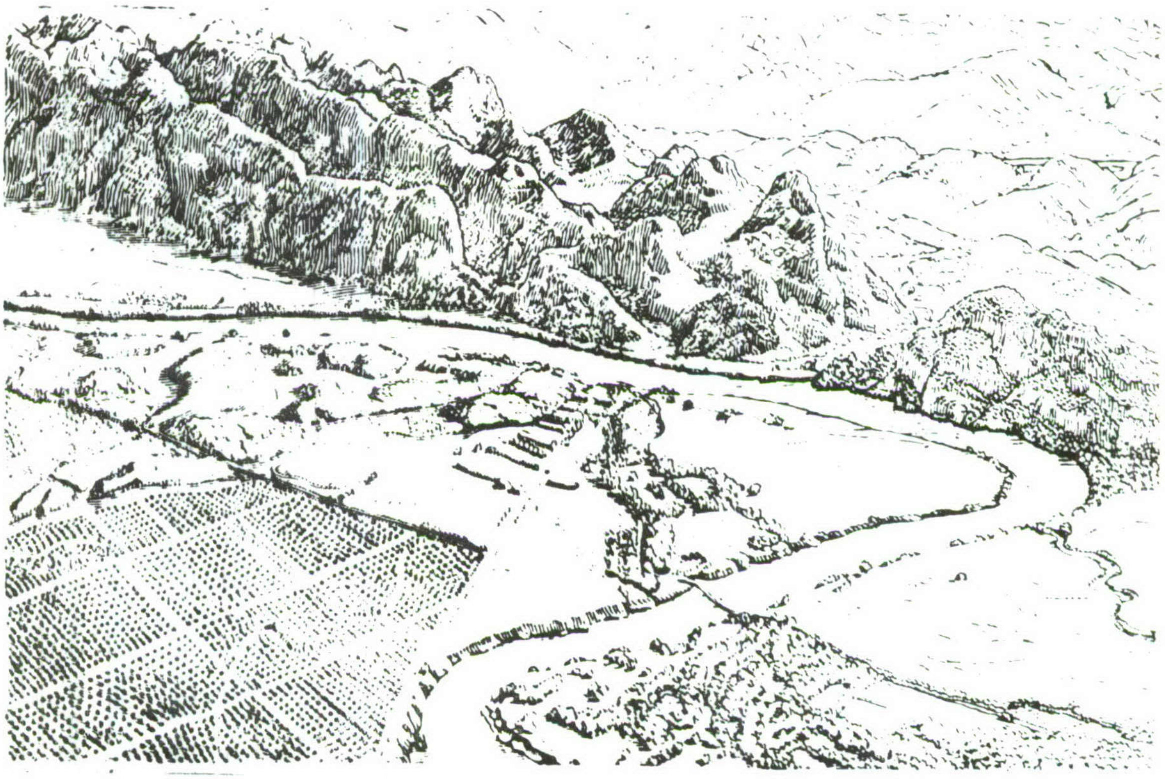
[redacted]



Rugged mountains and deeply cut valleys largely represent the Laos Plateau. Nearly covered with dense forest, the white squares represent agricultural fields cleared by the slash-and-burn method.

FIGURE 14

[redacted]

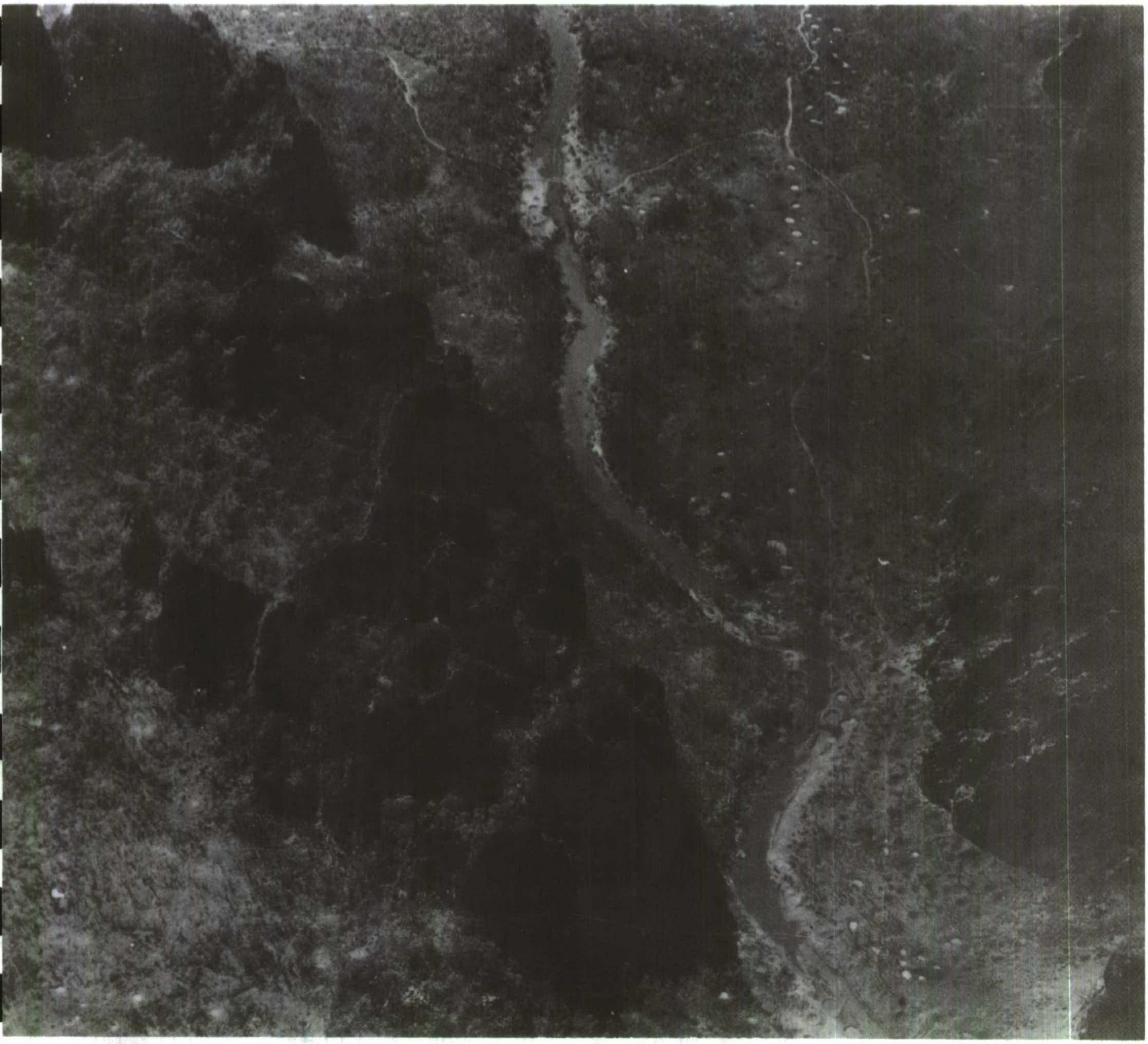


Rugged limestone hills, covered with forest to their summits, rise abruptly from western flat lowlands of the northern Deltas.

SOURCE: Indo-China

FIGURE 15

[redacted]



Rugged limestone hills (karsts) in
STEEL TIGER Area of Laos.
FIGURE 16

[redacted]

Annamite Chain

This southernmost spur of the rugged Himalayan Mountains originating in Tibet and China is the dominating physiographic feature of the entire Southeast Asian subcontinent. This region corresponds to parts of Route Packages 1, 2, and 3, as well as I and II Corps Tactical Zones. The chain extends southeastward, forming the boundary between Vietnam and Laos and between South Vietnam and Cambodia. In the strictest sense, it is not a true mountain chain, but rather a series of eroded plateaus dominated by high, isolated peaks. The chain is irregular in height and form, with numerous spurs dividing the coastal strip into a series of compartments.

The northern portion of the chain in North Vietnam and Laos is narrow and very rugged. There are extensive areas of karst in the Lao portion which contain areas of jagged peaks honeycombed with caves and solution basins (Fig. 16). The peaks of the chain range from 5,000 to 8,500 feet in height.

In the southern portion, a large plateau, known as the Central Highlands covers an expanse of some 20,000 square miles. It is divided into two distinct parts. The northern sector, known as Cao Nguyen Dac Lac, extends about 175 miles north from the vicinity of Ban Me Thuot (RVN), to the Ngoc Ang Peak. Varying in elevation from 600 to 1,600 feet with some high peaks, it is irregular in shape and is covered mainly with bamboo and tropical rain forest. The southern sector is higher in elevation, averaging more than 3,000 feet. Forest growth consists mainly of rain forest in the higher elevations and bamboo on the lower slopes.

In Laos, the Bolovens Plateau is made up primarily of basalt from ancient lava flows with several sandstone peaks standing above the general terrain. There is a gentle slope leading to the surrounding plains except on the eastern side. The plateau is predominantly grassland.

In general, the whole physiographic region is covered with tropical rain forest, interspersed with areas of monsoon forest, savanna grass, and bamboo forest.

Extending along the sea from the Mekong Delta to Vinh Son (NVN), the Coastal Lowlands Region, rather than being a continuous lowland area, is segmented by spurs of the Annamite Chain coming down to the sea. In other areas, the flatland extends 40 miles inland. From the Mekong Delta, an infertile coastal strip, generally narrow and covered with shifting sand dunes, extends northeastward about 100 miles to Mui Dinh.

From Mui Dinh northward, the coastal plain remains narrow for about 100 miles to Mui Dieu, where a mountainous spur reaches the sea. The most extensive and fertile plains of the Coastal Lowlands are on the strip farther north to Da Nang, a distance of some 250 miles where two rice crops are grown each year. Formed by rivers, there are broad plains extending westward toward the mountains; the most significant of these are found along the Thu Bon River which empties into the sea at Hoi An. Between Da Nang and Hue, 50 miles farther up the coast, mountain spurs jut into the sea. From Hue to Vinh Son, much of the shore is fringed by a narrow line of sand dunes backed by an extensively cultivated, flat, and fertile area.

Natural vegetation in the mountain spurs is tropical rain forest and sand dune areas are clear, with the fertile areas cultivated. Except for the Mekong, this is the most densely populated region of the Republic of Vietnam.

Cambodian Plain Region

With III CTZ located in its southeastern area, the Cambodian Plain region is nearly level, except in a few places where low, rounded hills break the surface. Modern alluvium and ancient alluvial terraces constitute the greater part of this area, and the major physical feature is Tonle Sap, a massive lake--originally an arm of the sea. Due to a rise in shore level, the Mekong extends its course southward, preventing movement of tidal waters into Tonle Sap. The lake is connected to the Mekong at Phnom Penh by a 40- to 50-mile channel called the Tonle Sap River.

The water level in Tonle Sap varies with the season. At low water, from November to June, the lake drains into the Mekong. During this period, Tonle Sap covers about 1,000 square miles, measuring 100 miles in length and 22 miles at its widest point, with a maximum depth of six feet. From June to October, however, the direction of flow is reversed due to the greater height of the Mekong. The adjacent plains are flooded and the Tonle Sap extends its area to 3,900 square miles. It becomes more than 185 miles in length and 60 miles in width in certain areas, with a maximum depth of 46 feet.

The area east of Tonle Sap has more varied relief than other parts of the region, and alluvial deposits are restricted to a narrow zone bordering the Mekong. Mangroves are found on the alluvial flats of Tonle Sap, with much of the area cleared and cultivated. There are small upland areas near Khone, whereas south of Kratie, the ground is slightly undulating, with the Mekong cutting through in a series of rapids. The region contains some rain forest, monsoon forest, and savanna grass.

Mountains of Southwest Cambodia

The region of the Mountains of Southwest Cambodia is characterized by a densely forested, compact mass of plateaus and mountains, with an average elevation of about 3,300 feet. Two broad zones of relief are distinguishable: a low, broken plateau zone rising immediately to the southwest of the Tonle Sap alluvial plain and a high plateau zone, including the Cardamom Mountains composed of rocky summits, deep valleys, and steep slopes on nearly every side. Several peaks reach over 4,500 feet and a large portion of the mountain range is covered by an extremely dense forest. The Elephant Mountains have very steep slopes on every side, falling to the sea in an almost vertical face more than 3,000 feet in height.

Mekong Delta

The Mekong Delta, which includes southeastern Cambodia and IV CTZ, is a diamond-shaped region with the northernmost apex located just south of Phnom Penh, where the river splits into two channels: the eastern branch, still known as the Mekong, and the western branch, called the Bassac River in Cambodia or the Song Hau Giang in the Republic of Vietnam. Both branches flow through the Mekong Delta in the latter country into the South China Sea.

The less fertile delta of the Van Co Tay, Vau Co Dong, Saigon, and Dong Nai Rivers extends to the east of the Mekong. The whole area is a monotonous plain with few parts more than ten feet above sea level. The fertile delta soil consists of river mud interrupted by long, narrow deposits of sand. The land is intensively cultivated and supports a dense population.

In the Republic of Vietnam, the Delta proper covers approximately 26,000 square miles. So much sediment is carried to the sea that the coast line is advancing as much as 260 feet per year. The southernmost tip of the delta, called the Mu Bai Bung, is covered with dense jungles, whereas much of the Delta coast is covered with mangroves.

Summary

A complex interaction of physical elements creates the environmental matrix of each of the physiographic regions--each having features distinctive from the others, while retaining a general similarity. Local variations in relief usually are responsible for the greatest effect upon weather, with precipitation leading to differences in vegetation and soils.

This geographic backdrop provides insight into the complexity of the environmental frame within which the Southeast Asia conflict is being conducted. Since climate, vegetation, and terrain significantly affect tactical air operations, these geographic insights offer the military planner a better understanding of the environment of each physiographic region of Indochina.

CHAPTER II

PROBLEMS OF ENVIRONMENT

In most phases of tactical air operations--strike, reconnaissance, or rescue--the common denominator was target acquisition. Strike aircraft were required to locate targets for delivering ordnance. Rescue helicopters were used in locating downed personnel, and the Forward Air Controllers' duty was to identify potential targets through visual reconnaissance (VR), so they could call in strike aircraft. Reconnaissance aircraft used various forms of sensors, including cameras, infrared (IR), and radar equipment to obtain imagery of assigned targets and record potential target areas. This imagery was evaluated by Photo Interpreters (PIs) who assessed target conditions and identified possible targets on the ground.

All of these aerial efforts were affected in one way or another by one, or a combination of several environmental variables--primarily weather, darkness, vegetation, and terrain. Although the effects of weather and darkness have been detailed in CHECO Report, "Impact of Darkness and Weather on Air Operations in SEA,"[1/] some attention must be given to the effect of monsoon rains on tactical aircraft. The primary difficulty was the effect of weather on marginal airfields which rendered these sites unusable over extended periods of time. This was true particularly in the Mekong Delta region where certain runways with poor drainage remained under water for the entire southwest monsoon season. Even on those fields where runway matting was used, erosion of

[redacted]

the subsurface material was so extensive that major subgrade repair and replacement of matting became an annual project.[2/]

Difficulties were encountered in the construction of some of the air bases in South Vietnam. The initial operational capability of Phan Rang, for example, was a 10,000-foot AM-2 runway.[3/] The runway withstood the operational wear until the first torrential rains arrived during the southwest monsoon. According to the 7AF Historical Division:[4/]

> *"...with the first of the torrential rains, the base course and subgrade began to fail. The first evidence of these failures showed on the aircraft parking ramp where the 554th was erecting Armco revetments. It was thought at first that the six-inch depression which had formed under the matting in one particular spot was an isolated instance but, as the rains continued, 90 percent of the ramp was similarly affected. Base course depressions soon deepened far beyond six inches, filling rapidly with water and occasionally causing the fighter-bombers to drag their wing-hung ordnance. The ramp failure spread next to the taxiway, then to the runway."*

Problems of Vegetation

The problems of vegetation as they applied to air operations were perhaps best identified by the Herbicide Policy Review Committee, a group organized by the U.S. Embassy, which included Senior Representatives of MACV, U.S.AID, and JUSPAO:[5/]

> *"Much of South Vietnam...is covered with dense forests, jungle, and mangrove. Utilization of this natural concealment has afforded the enemy great tactical and logistical advantages vis-a-vis Allied forces. A paramount military problem from the outset, therefore, has been the difficulty of locating the enemy, his bases, and his LOCs. Without information about enemy*

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Cleared farmland surrounded by forest is typical scene in Indochina. Dense vegetation offers excellent cover while cleared area becomes hazardous for VC/NVA movement. FIGURE 17

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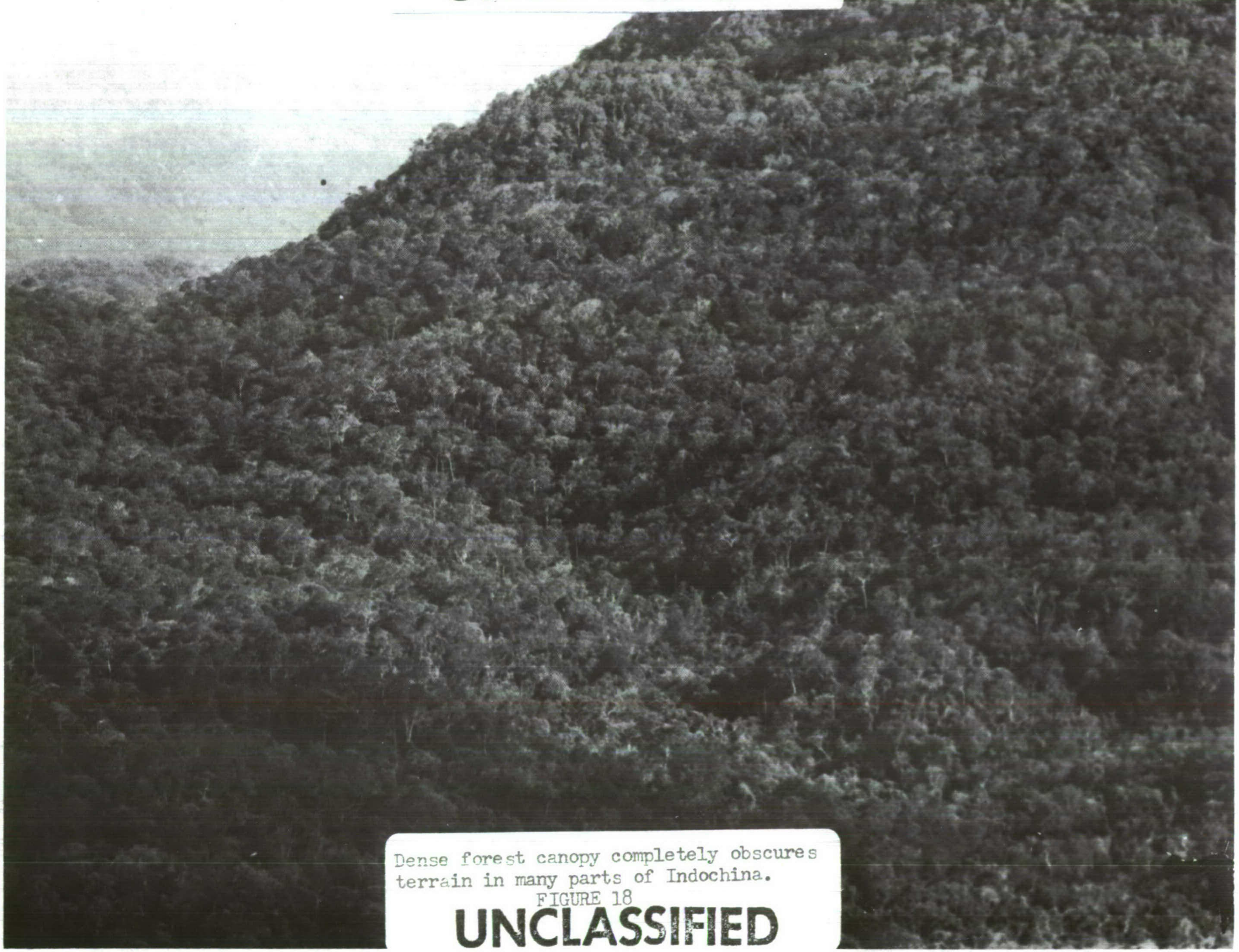


Dense forest canopy completely obscures terrain in many parts of Indochina.

FIGURE 18

UNCLASSIFIED

dispositions, our forces cannot exploit their advantage of superior firepower."

This appraisal also applied to the major forested areas of the remainder of Indochina.

The VC/NVA forces were well aware of the advantages of cover. Information gleaned from Department of Defense Intelligence Information Reports indicated the enemy was well briefed on the significance of the forests. The 6499th Special Activities Group (SAG) reported:[6]

> *"Troops in movement feel that the best protection against FACs is to go unnoticed from the air. If the terrain through which they are moving affords them the luxury of triple canopy, they have little to worry about. Problems arise when they must cross openings in the jungle."* (Fig. 17)

One NVA prisoner told his interrogator,[7]

> *"If the infiltrators were in a rest area and an aircraft approached, they were to stand still. Although the infiltrators did not wear camouflage in the rest areas, the thick jungle canopy above the rest areas and the lack of motion under canopy would make it difficult to be detected from the air."*

Tactics of this type made employment of tactical air more difficult. (Fig. 18 illustrates the density of the forest canopy.)

Reconnaissance

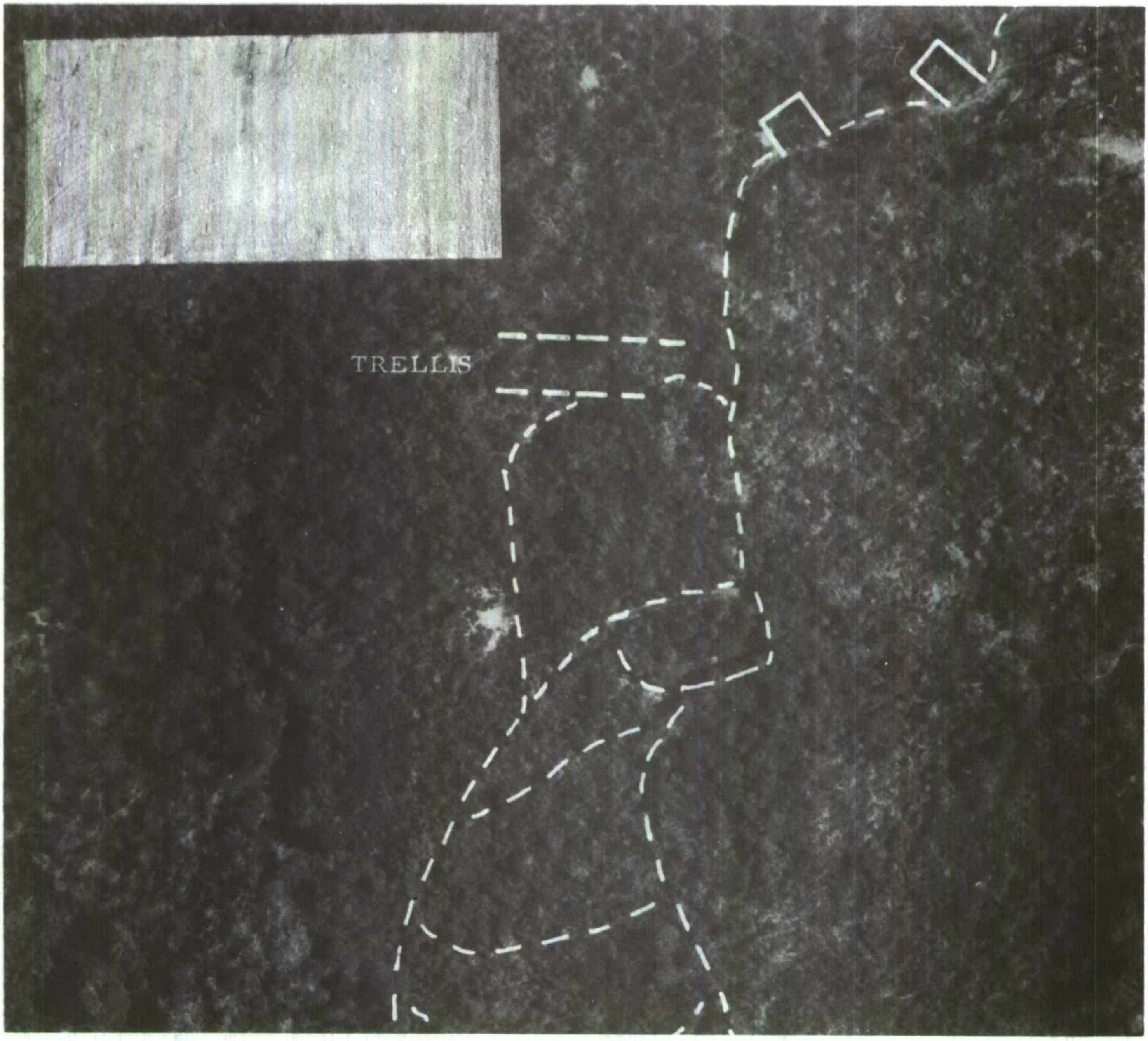
Three different categories of reconnaissance were used by USAF in Southeast Asia: imagery sensing obtained by aircraft; VR by FACs; and the use of IGLOO WHITE acoustic and seismic sensors. The major problem of imagery sensing was readout and identification of targets in heavily canopied areas (Fig. 19). In rain forest, mangrove, and wet season monsoon forest, it was always difficult and sometimes impossible to obtain essential elements of information through photo interpretation.[8/] Monsoon forest was also difficult to interpret in the dry season due to shadows cast by the leafless trees.[9/] The use of camouflage detection film did aid, however, in locating hidden enemy locations. Vegetation often affected reconnaissance tactics, since it was difficult to find navigational reference points in forest areas. Great difficulty was also experienced when parallel flight lines were required. It was often possible, however, to use a prominent nearby geographical feature, such as a river, as an initial point. Target coverage was then accomplished by flying precise headings and times from the IP.[10/]

Infrared (IR) also offered help in obtaining Essential Elements of Information (EEI). This innovation was appraised in the Special CHECO Report, "USAF Reconnaissance in Southeast Asia, (1961-66)":[11/]

> *"In counterinsurgency operations, IR may be used to detect cooking, lighting and sentry fires, water and roadway (limited) surveillance, manufacturing activity, some trail detection, and agricultural and vegetation studies."*

Regarding limitations to the use of infrared, it was not always able to penetrate forest canopy. The different heat layers emitted from multiple canopy forest in contrast to the temperature of the forest itself masked sources under the canopy. Single canopy forest, however,

[redacted]



Heavy forest canopy plus planned camouflage efforts provides VC/NVA good concealment for truck parks and storage areas.

FIGURE 19

[redacted]

did provide opportunities for the gathering of essential elements of information with IR. The IR equipment on the RF-4C could be used to obtain road reconnaissance if conditions were right. There was a period of two to three hours in the early evening on sunny days where roads under the forest would emit enough heat to be identified through a transparent window in the canopy. Under these conditions, data could be obtained if the aircraft were flown at approximately 1,000 feet above ground level (AGL).[12/]

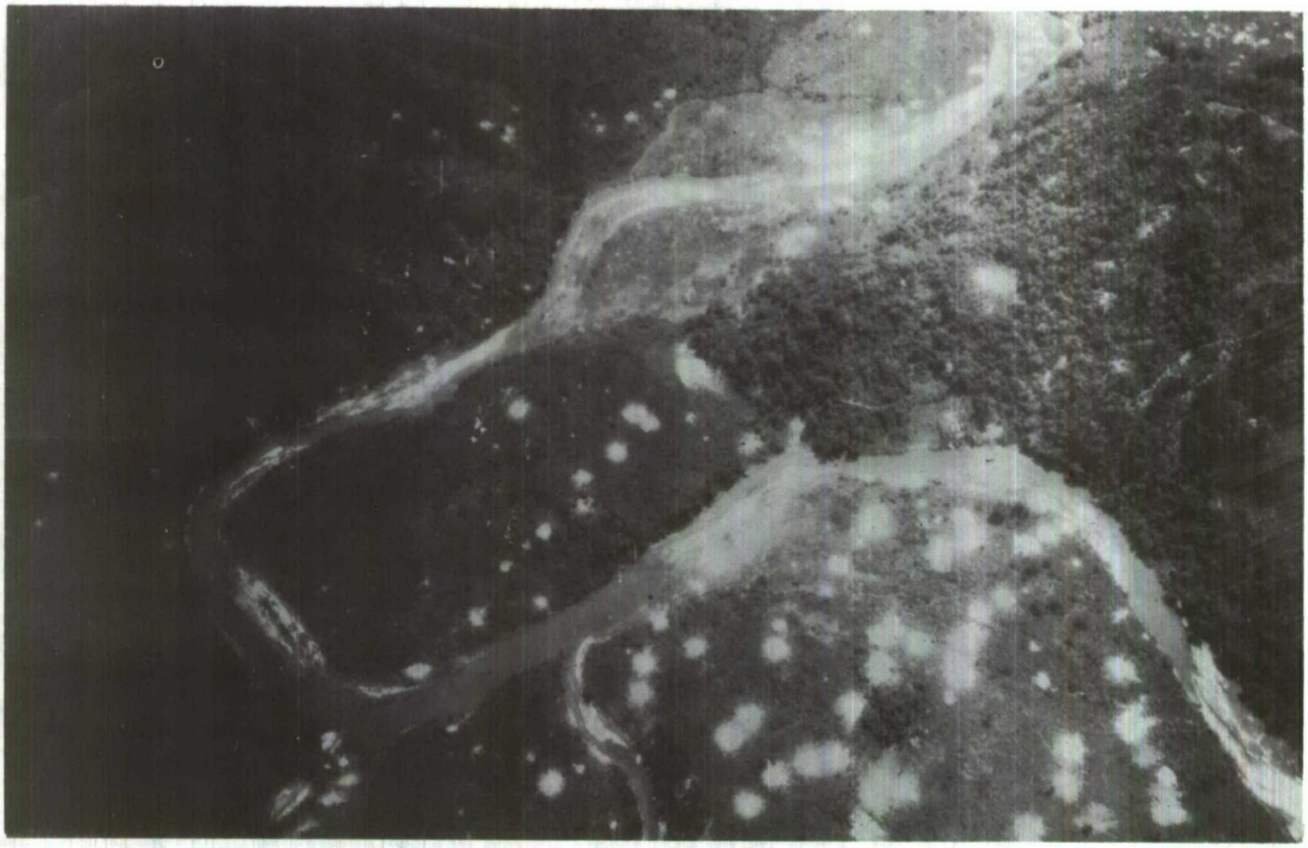
One of the key problems with IR was photo interpretation. Technicians were not properly trained in its interpretation at the appropriate technical school and therefore required extensive OJT in the war zone. Infrared did prove effective, however, in obtaining general reconnaissance from one hour before sunrise and sunset until one hour after these times.[13/]

In visual reconnaissance, the FAC's problems were magnified even further. PIs had time to evaluate photographic results, while the FAC had to make instantaneous judgments as he was flying over the landscape. Slow moving FACs had advantages over jet FACs. All had difficulties with vegetation. It took a new FAC approximately one month to learn his area well in good weather.[14/] He had to become familiar with many visual reference points to be effective in directing strikes. Multiple-canopy rain forest limited his ability to perform VR. Single-canopy and defoliated monsoon forest did not necessarily ease the VR problem. A paper prepared for the 20th Tactical Air Support Squadron (TASS) stated these instructions:[15]

> *"Large portions of any jungle area are impossible to VR due to the jungle whether high or low. In general, you should avoid these areas for two reasons. The obvious reason is that your eye cannot penetrate this green mantle and second forced landings in these areas are hazardous. This does not mean you should eliminate these areas completely since at various times of the year the foliage is less dense and you can catch glimpses of the jungle floor. At these times, you might sight a trail or structure. Briefly, an occasional overflight will be sufficient for VR purposes."*

Fast moving FACs had the same problem intensified by much faster speeds. They simplified their problem, by using the names given to unmistakable physical features.[16] Figure 20 illustrates the "Dog's Head" and the "Heart," prominent river meanders in Laos. Reference to features of this type enabled FACs to more accurately locate targets. In time, these VR points became widely known and used by aircrews flying many types of aircraft to accurately locate FACs and targets.[17]

The third intelligence gathering system, IGLOO WHITE, involved use of acoustic and seismic sensors for detecting enemy vehicular and personnel movements. In the early phases, multiple canopy was prerequisite to the placement of the ACOUBUOY acoustic sensor which was designed to hang in trees or foliage by its parachute. This type of sensor could not be emplaced where trees were sparse or nonexistent. Accordingly, a variation called SPIKEBUOY, was introduced without a parachute, and with a spiked nose designated to penetrate the ground. As this innovation came into use, forested areas became a hazard rather than a help. SPIKEBUOY, ADSID,



Dog's Head (top) and "Heart" (bottom) are prominent river meanders in Laos used as significant landmarks.
FIGURE 20

and ACOUSID, could not be emplaced as accurately in very densely canopied forest areas. The devices would tend to bounce off the upper branches of the trees causing the devices to miss their aiming points. Additionally, survivability of the device was estimated to be only 65-75 percent, due to damage incurred by the forest.[18/] Open forest with its sparse canopy had no appreciable effect.

Other methods were devised for locating enemy emplacements under forest canopy. The EC-47 was introduced with a capability for accomplishing airborne radio direction finding (ARDF). Through the use of special tactics, these aircraft were able to accurately locate radio transmitters. A full evaluation of the EC-47 was presented in the Special CHECO Report, "The EC-47 in Southeast Asia."[19/] Another technique was use of interrogation reports which provided intelligence from captured enemy troops and ralliers indicating the possible location of VC/NVA base camps and caches.

Strike

Vegetation affected strike aircraft in a limited way. Strike pilots delivered ordnance as directed by FACs, for the most part, attacking the points marked by smoke. As indicated by two crew members of the 366th Tactical Fighter Wing (TFW) at Da Nang AB:[20/]

> *"Vegetation, first of all, makes it hard to acquire the target. Secondly, it makes it hard for the FACs [that combined with the debris and smoke coming up from the bombs themselves] to direct you to make small corrections around the target area. And it makes it hard for them to read the BDA after it is over with."*

Some problems were encountered with ordnance. A steeper dive angle

(20-30°) was required for delivery of unfinned napalm in a forested area. Although the burn pattern was reduced, it enhanced penetration of the trees.[21]

The BLU-3/B bomblet, delivered in a CBU-2/A by the F-100, F-105, or F-4, was designed for used against personnel and light or thin-skinned targets. Each bomblet detonated on impact, propelling 250 steel balls at an initial velocity of 4,000 feet per second. Effectiveness of the weapon was degraded, however, when it was delivered in forested areas. Tree limbs either actuated the bomblets, causing them to detonate at heights which negated their antipersonnel value, or caused them to tumble to the ground resulting in a high dud rate.[22] In late 1969, the weapon was phased out of use.[23]

The BLU-24/B, on the other hand, was designed for use in foliage. It was an antipersonnel and anti-materiel weapon for use in heavily forested areas where effectiveness of other types of cluster bombs was degraded. Armed by spin fins, it detonated by spin decay caused by the weapon being slowed by foliage. It could be carried by the A-1, A-26, A-37, and T-28 aircraft.[24]

There was some effect on bomb fuzes by vegetation. Fuze extenders, consisting of an explosive-filled length of steel tubing, were installed in the nose well of bombs with instantaneous fuzes in the forward end of the extenders. This arrangement enabled the bomb to detonate as soon as the fuze at the forward end of the extender contacted the target while the bomb was still three feet from the target. Both blast and fragmentation effects were improved in this way. This weapon proved to be very effective against troop concentrations in forested areas.[25/]

Similarly, there was concern over the effectiveness of ARC LIGHT strikes in forest areas. Early in 1967, Seventh Air Force observed that field reports covering ground bomb damage assessment (BDA) of ARC LIGHT strikes had revealed that dense forest canopy had caused all of the bombs to explode before reaching the ground, creating little or no damage to enemy installations. As a solution to the problem, COMUSMACV recommended fuzing the bomb with an external .025 delay fuze and an internal .10 delay fuze. MACV was advised that all loaded bomb stock on hand would have to be used until the supply was expended.[26/]

On 30 March 1967, COMUSMACV requested that all MK-82 sorties be equipped with .025 delay fuzes in both nose and tail, if the .01 delay fuze were not specifically requested in the strike message. Strategic Air Command (SAC) replied the proposed fuzing would permit the weapon to penetrate approximately 20 feet prior to detonation which would result in the earth exploding upward and falling back into a crater about 20 feet in diameter. In this situation, little or no clearing of forest vegetation could be expected around the crater. SAC further argued that if the proposed fuzing were made with the idea of avoiding tree-bursts, the difference in burst height between the .025 and the .01 setting was about 15 feet[27/] as reported in the special CHECO report, "ARC LIGHT: January - June 1967:"[28/]

> *"Fuzing, which had been suggested by SAC on 29 March, was designed to obviate tree detonations and to provide optimum effects for surface and subsurface detonations. Blowdown from a surface burst should measure approximately 130 feet in diameter. The crater size for an .01 fuze would be about 30 feet in diameter, and some 10 feet in depth, with an associated jungle clearance of an area of about 60 feet in diameter. For this reason, SAC was anxious that SAC ADVON expedite discussion with MACV relative to these points."*

Questions were also raised concerning the types of bombs to be used for the best effect on ARC LIGHT strikes. SAC supported the M-117 as a superior weapon to the MK-82 by citing the following statistics:[29/]

> *"...the total jungle blowdown possible, with surface detonation from 66 M-117s was about 1,500,000 square feet as opposed to 1,400,000 square feet for 108 MK-82s. In addition, the total area that could be cratered with optimum subsurface detonations was approximately 65,000 square feet for a full load of M-117s as compared with approximately 57,000 square feet for a full load of MK-82s."*

During the COMMANDO HUNT III interdiction campaign in the northeast monsoon season from November 1969 to May 1970, B-52 aircraft carried mixed loads of M-117s and MK-82s.[30/]

There was great difficulty in accomplishing BDA for ARC LIGHT strikes. With the vast majority of targets located in multiple-canopy forest and a bombing altitude of 30-33,000 feet, it was impossible for B-52 crews to see the target or give an accurate estimate of the kind and degree of damage inflicted. The bombers did accomplish K-17 photography during daylight missions, but the photographs could be used only to measure circular error probable (CEP), bomb train length, and the number of bombs falling within the target box.[31/] BDA for these missions was provided in some cases by post-strike reconnaissance, by FAC VR, and, in-country, by ground teams, because reconnaissance suffered from some of the shortcomings discussed previously.

Heavy canopy could deter gunship operations depending on sensor equipment of the particular aircraft and density of the canopy. Shadow AC-119G gunships had no IR and on occasion were required to fire into forested target boxes. They would fire 6,000 rounds. If no secondary explosions or return fire were noted, they would fly on to their next target. BDA was impeded by heavy cover.[32/] Stinger AC-119K gunships, on the other hand, were equipped with IR which could penetrate canopy to some degree depending on the density and heat emission qualities of the prospective target. The destruction of much vegetation along heavily used LOCs in STEEL TIGER diminished its effects on their mission.[33/] In addition, Hunter-Killer teams of Army OV-1 Mohawks equipped with side-looking airborne radar (SLAR) worked with Air Force AC-119 gunships in STEEL TIGER to effectively locate and destroy enemy targets during COMMANDO HUNT III.[34/]

Spectre AC-130 gunships were equipped with several varieties of sensors to enhance target acquisition. Among these were IR and a night observation device (NOD). These gunships normally operated at 5,000 feet AGL over LOCs in Laos. Due to the limited range of the IR, detection capability decreased significantly above this altitude. In addition, effectiveness of the NOD was greatly reduced above this altitude if visibility fell below three miles.[35] The effects of vegetation on Spectre can be appraised from this narrative of a typical mission:[36]

> *"[Friendly] troop positions were plotted by means of reflective panels and strobe lights prior to firing. The terrain was very hilly and covered with a dense jungle canopy. Although the weather was generally clear with occasional haze, the marking devices could be observed only when the aircraft was in a very steep bank and tightly orbiting over the position. Because of this and the presence of other units in proximity, it was very difficult to keep oriented on a specific point while the aircraft was using pylon turn geometry.... Firing was reported to have been delivered in the target area, but BDA was impossible because of the dense canopy."*

Another mission narrative explains the use of NOD and IR.[37]

> *"The NOD detected a target that appeared to be three trucks fording a stream. The visible lights were picked up at a distance of approximately 10,000 feet with the aircraft at an AGL of 3,000 feet. The trucks were dispersed; one had crossed the stream, and the other two were ready to cross. The trucks were attacked by the aircraft using pylon turn geometry and the computer in the NOD mode. After the firing, the trucks turned off their lights. The first truck was probably destroyed and one of the others damaged. Two flares were then dropped, and the IR, which had been scanning continuously, then detected eight more hot spots under the trees. These spots were considered to be trucks and were fired upon with unknown results."*

Vegetation had no effect on ordnance used by gunships. Tests were run to evaluate effectiveness of 7.62-mm and 20-mm ammunition in forest canopy. A test target was established in single canopy rain forest in Thailand which had 60-foot trees. The area, 60 feet square on the ground, was covered with paper. The aircraft made three attacks from 4,500 feet AGL using one gun of each caliber. Two hundred rounds of 7.62-mm ammunition, 100 rounds of 20-mm HEI, and 100 rounds of 20-mm API ammunition were expended. Although an exact count of projectiles could not be made, there was sufficient evidence on the rocks, ground, bamboo, and tree trunks to indicate that all three types of projectiles penetrated the canopy. All bursts were observed to impact in an area of about 45 feet by 95 feet.[38/]

<u>Rescue</u>

As with strike aircraft, the rescue helicopter had to know the precise location of its target--a downed airman. Visual reconnaissance in heavy canopy impeded finding an individual. The downed pilot had pen-gun flares, smoke grenades, a signal mirror, colored panels, a strobe light, and, if all else failed beneath the thick forest canopy, .38 tracer ammunition to make his exact location known.[39/] Lowering rescue equipment to the person on the ground was usually not prevented by the forest because rescue aircraft were equipped with a tree penetrator, a bullet-shaped device, which was furnished with retractable seats and safety belts.[40/] However, problems were sometimes induced by the helicopters themselves:[41/]

> *"The flight engineer had difficulty penetrating the trees with the penetrator due to the swaying from the rotorwash. With the rotor tip path three feet from the treetops and the tail rotor the same distance, over 230 feet of cable were required to reach the survivors."*

The forest canopy was so dense in some cases as to prevent the smoke from flares from penetrating its foliage. Debriefing reports taken from rescued pilots indicate some of the problems encountered.[42/]

> *"At approximately 1755 [the Sandy] advised me to pop my MK-13 flare. I did so and the smoke went up and hit the jungle canopy and drifted down the hill, finally coming out at the base of the hill and to my right approximately 50 meters. I also popped the night end of the flare hoping the Jolly would see it and come over to me; however, he hovered directly over my smoke and began to lower the penetrator. I was unable to contact him on the radio at this time."*

The pilot was finally able to contact the Jolly and directed him up the hill toward his true position. The helicopter moved to within 30 yards of his position which he considered adequate. He made it to the penetrator and was rescued.[43/]

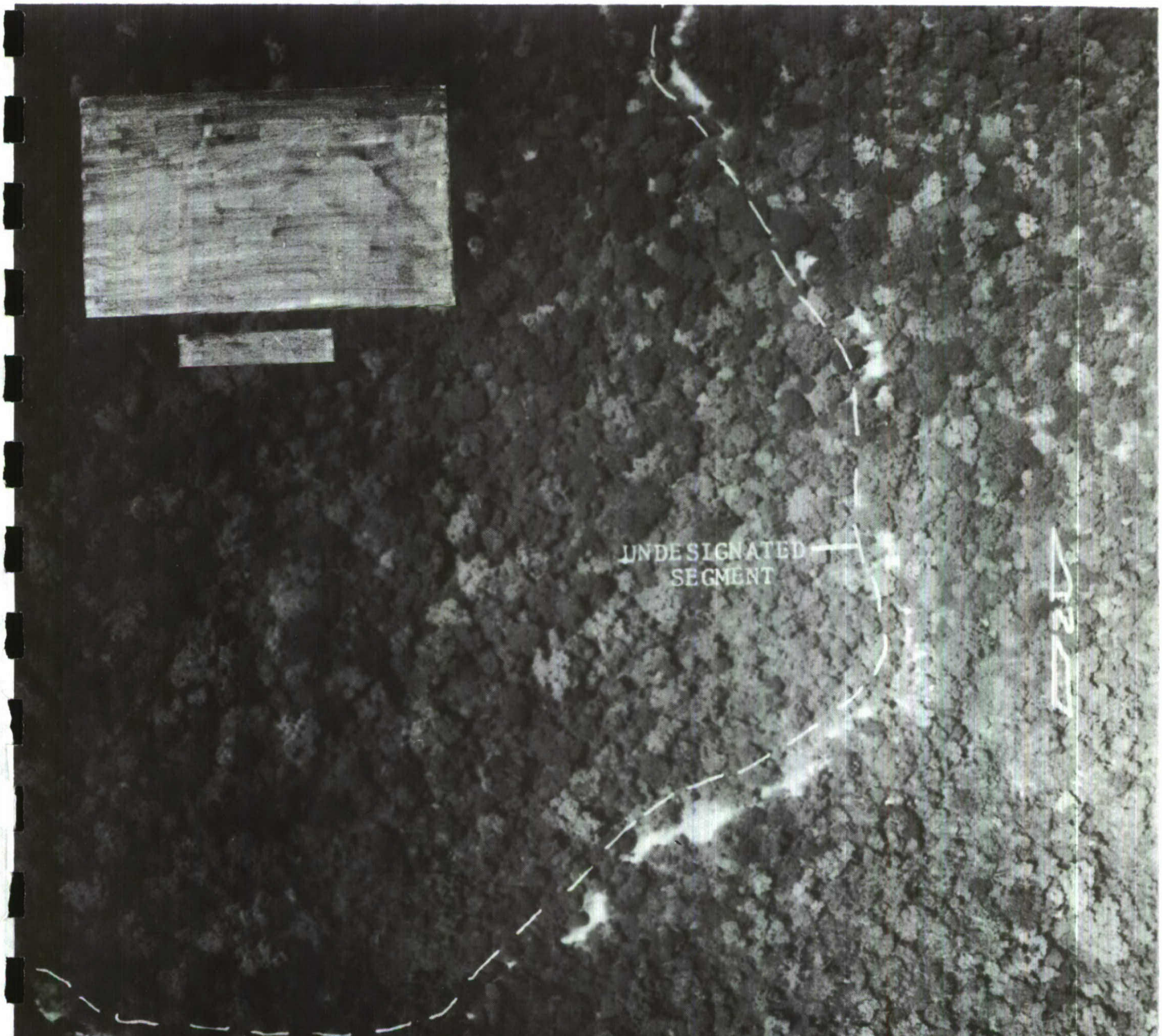
In another search and rescue (SAR) effort, similar problems confronted the pilot and his rescuers:[44/]

> *"The first aircraft I contacted in the morning was an OV-10, Nail 44, at about 0530L. I came up on voice and beeper. I later contacted Nail 51, some Spads and then Sandy 01. There was an overcast layer and fog in the valley, making it difficult for them to locate me. Since I had put in a strike nearby, about one hour before bailing out, I knew the approximate coordinates of my position and passed them by voice to the SAR aircraft. They did not determine my exact position until the Jolly Green Giant came in. I used two MK-13 flares, but they were useless since the smoke was not breaking the canopy. I did not use the night ends because the foliage was too thick. I used my compass and radio to vector the helicopter. I could not hear him very well due to the engine*

UC-123 aircraft flying a defoliation mission.

FIGURE 21

[redacted]



New road construction in Laos is partially seen through multiple canopy-- only clearance of vegetation allows surveillance.

FIGURE 22

[redacted]

noise of the Sandies and FACs, so I asked them to move out of the valley while the chopper was vectored in. The chopper could not see me, although I could see him through the trees. The penetrator was dropped about 20 feet from me."

Elimination of Cover

With the problem of vegetative cover recognized early in the SEA conflict, the idea of defoliation of forest canopy was introduced. (Fig. 21) The first experimental mission by RANCH HAND C-123 aircraft was flown on 12 January 1962.[45/] The purpose of the program was to eliminate enemy camps and secure areas, to enhance vertical visibility in forest canopy for purposes of reconnaissance and interdiction, to minimize cover along LOCs so that ambush was deterred, and to destroy trees and vegetation surrounding base camps to aid in base security.[46/]

The major defoliation efforts using herbicides were carried on in-country. Some operations were performed in Laos beginning in December 1965.[47/] The primary purpose of operations in STEEL TIGER and BARREL ROLL was to expose enemy LOCs (Fig. 22). Missions were also flown to defoliate the Demilitarized Zone (DMZ).[48/] As of 1967, a total of 10,107 square kilometers of forest had been defoliated in South Vietnam alone, some of it being treated more than once.[49/]

In September 1968, PACAF reported to the Joint Chiefs of Staff:[50/]

"...defoliation provides a 68 to 90 percent improvement in vertical visibility, and a 50 to 70 percent improvement in horizontal visibility, which accounts for field commanders' endorsement of the defoliation program. Analysis of field commanders' comments

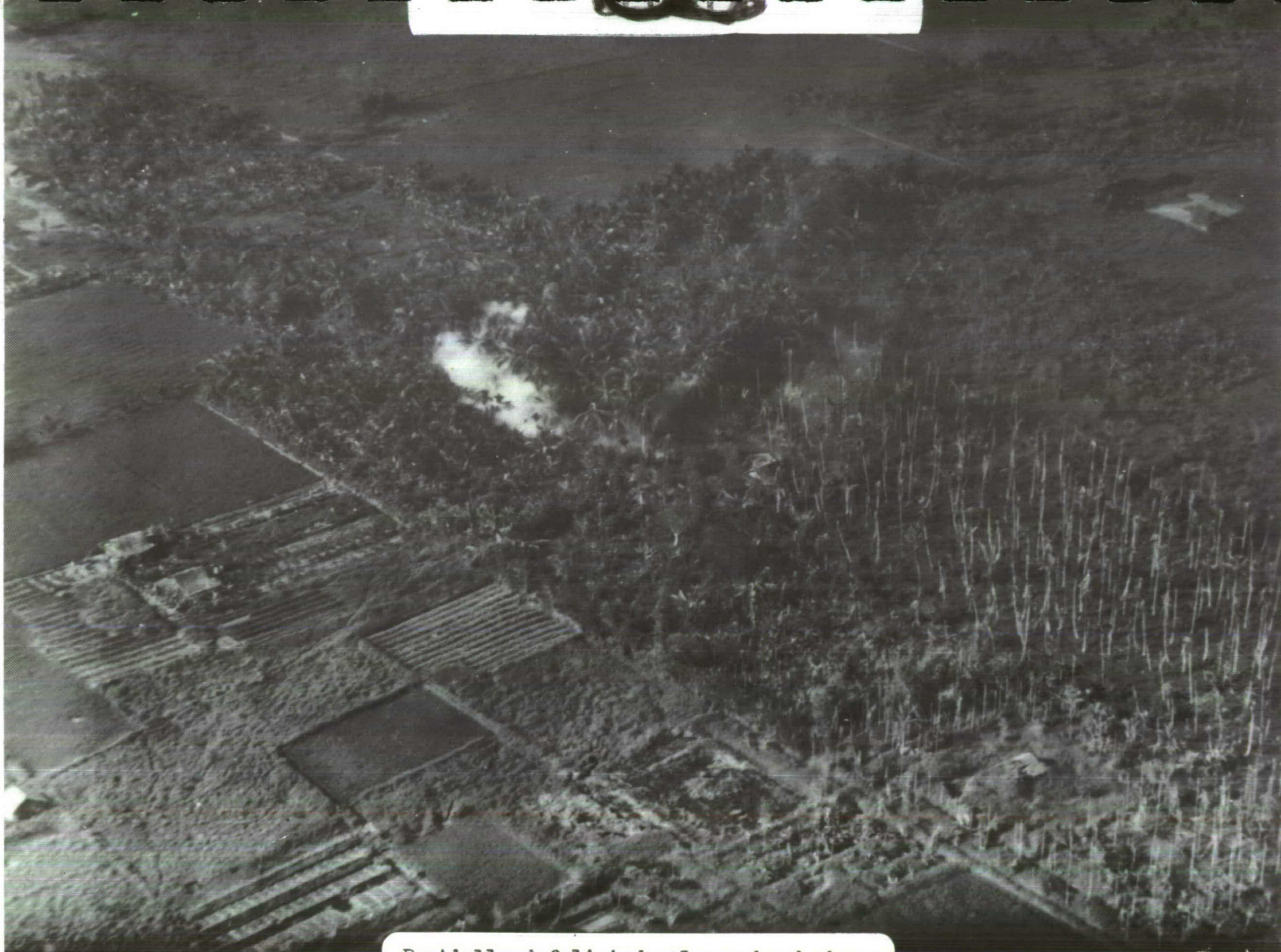
indicates that these operations have been instrumental in facilitating air observation of infiltration routes, uncovering enemy base damps, removing cover and concealment of enemy mortar and rocket launching sites, and have reduced the number of ambush locations along friendly LOCs." (Fig. 23).

With concern rising in the United States about the quality of environment and the effects of chemical agents on living things, thought was given to the military value of the herbicide program vis-a-vis the effects on the ecosystem. An ecologist from the U.S. Department of Agriculture was brought to Vietnam in 1968 to evaluate effects of the program.[51] As of mid-1968, the herbicide program was not a public opinion issue in the United States. It did, however, have a strong potential for trouble because of its high emotional content which was exploited by VC propaganda.[52] In early 1970, the U.S. press began to take strong notice of defoliation programs, as exemplified by an article in Time magazine, entitled "Operation Wasteland."[53]

In November 1969, the JCS sent a message to CINCPAC which quoted a memorandum by the Deputy Secretary of Defense:[54]

> *"A report prepared for the National Institute of Health presents evidence that 2,4,5,-T can cause malformation of offspring and stillbirths in mice, when given in relatively high doses. This material is present in the defoliant ORANGE.*
>
> *"Pending decision by the appropriate department on whether this herbicide can remain on the domestic market, defoliation missions in South Vietnam using ORANGE should be targeted only for areas remote from*

[redacted]



Partially defoliated palm orchard shows comparison of denuded trees with normal growth in center--leaf removal completely reveals floor.

FIGURE 23

[redacted]

population. Normal use of WHITE or BLUE herbicides can continue, but large scale substitution of BLUE for ORANGE will not be permitted."

The USAF requested $27 million for herbicide procurement for FY 71, however, the approved budget allowed $3 million for this purpose.[55/] This limited budget forced a reassessment of the entire program and these recommendations were made:[56/]

. Herbicide stocks on hand be reserved for high priority targets.

. Herbicide operations from 1 April 1970 through 30 June 1970 be phased down to 120 sorties per month.

. Reduce the 12th SOS to eight UE aircraft.

. MACV requested a capability for spraying herbicides be maintained for use on critical high priority targets.

The use of herbicides provided a useful military tool to obtain some visibility through the forest canopy. Justification for its use was explained in these terms:[57/]

"The defoliation program has been instrumental, and at times decisive, in overcoming the difficulty of locating the enemy in heavily forested combat zones. It has thereby helped enable Allied forces to maximize their advantage of superior mobility and firepower. It has also enhanced the security of Allied lines of communications and facilities by helping to eliminate enemy ambush sites and by providing defensive fields of fire. Thus, both offensively and defensively, defoliation has reduced the number of men and equipment required for combat missions, has protected war materiel, and most importantly, has helped to save many Allied lives."

Defoliation was also accomplished to some degree as the result of bombing with high explosives. Figure 24 illustrates the removal of vegetation along an enemy LOC as the result of ordnance. Defoliation was also accomplished as a by-product of ARC LIGHT strikes. Each B-52 produced a pattern approximately 30 to 50 meters wide by 2 to 5 kilometers long. There was 100 percent clearing around each crater up to a distance of 15 meters, depending on the density of vegetation (Fig. 25).[58]

Summarizing, heavy vegetation was the major deterrent to target acquisition in Indochina. Used effectively as cover by the enemy, USAF elements worked hard to overcome the limitations. Some relief was gained through use of IR and defoliation. Reconnaissance efforts, however, were hampered to a large degree. A report on FAC operations prepared by the USAF Combat Analysis Division indicated that of a sample 100 targets identified, 76 percent were located in trees.[59] Fifty-seven percent of the same sample was under heavy cover.[60] A Rand study indicated that:[61]

> "...*a better sensor is needed to detect targets through a jungle canopy if airpower is to achieve major successes in destroying trucks in truck parks.* [*Whether, in fact, such a sensor can be developed that will be operationally satisfactory in airborne use is somewhat doubtful*]."

Problems of Terrain

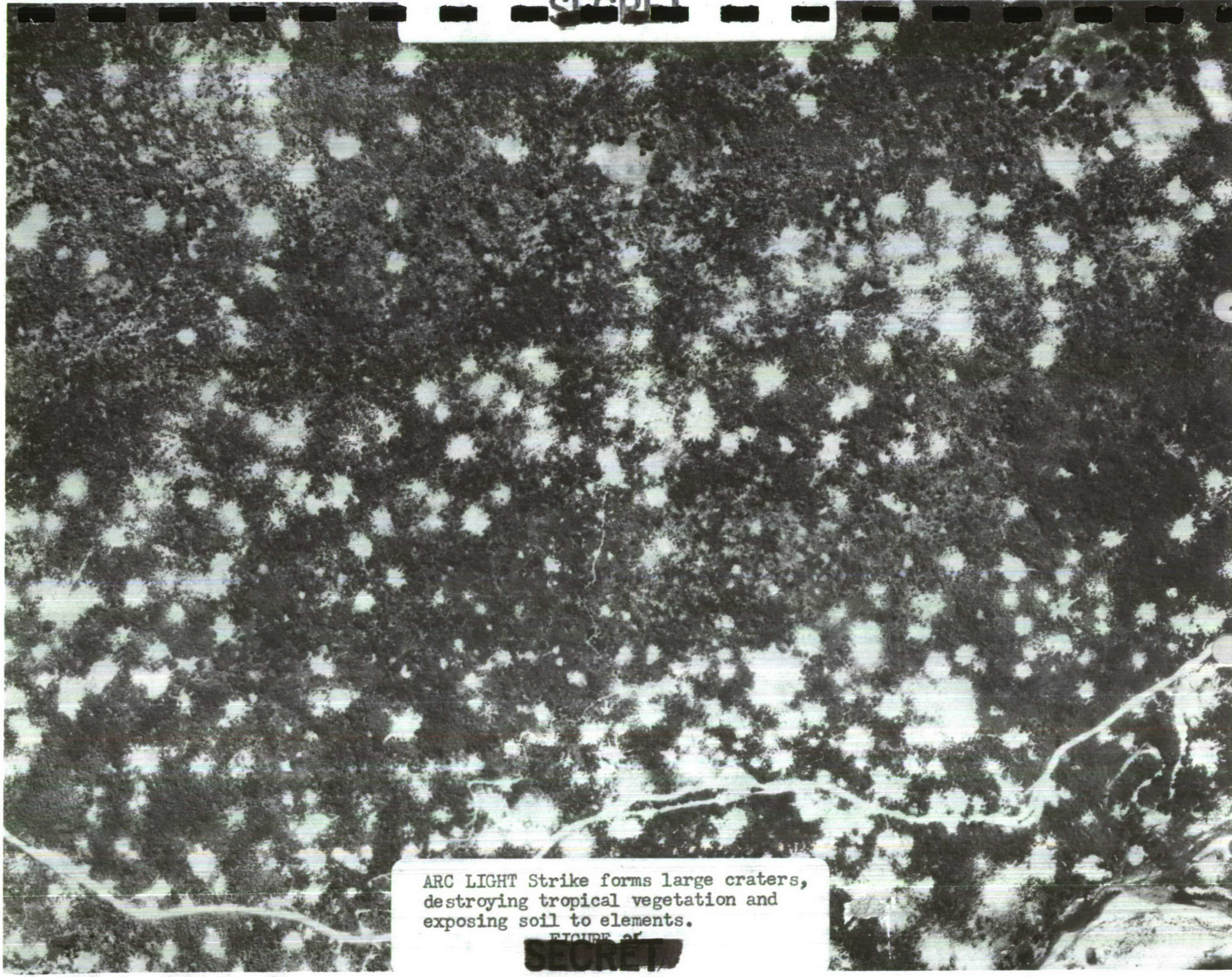
Terrain created two kinds of difficulty. It was used to some extent as cover by the enemy and it limited certain operational tactics. As cover for moving troops, the NVA would take advantage of the sun's position

CONFIDENTIAL

Continuous bombing along enemy LOC in
STEEL TIGER removed vegetation.
FIGURE 24

CONFIDENTIAL

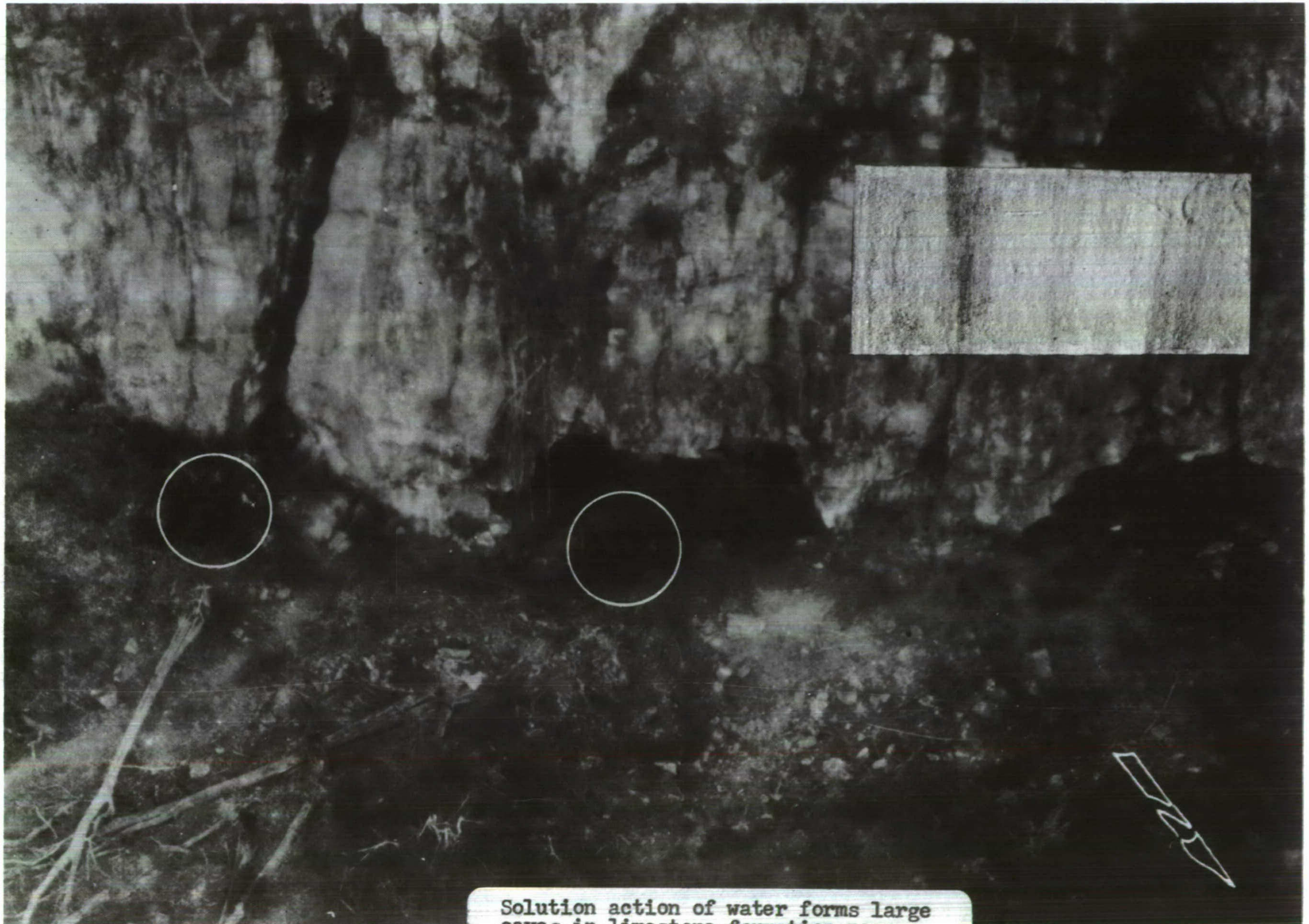
SECRET



ARC LIGHT Strike forms large craters, destroying tropical vegetation and exposing soil to elements.

FIGURE 27

SECRET



Solution action of water forms large caves in limestone formation near Mu Gia Pass.

FIGURE 26

to avoid disclosure. According to a briefing prepared by the 6499th SAG:[62/]

> *"One PW reported that his infiltration unit would walk on the eastern slopes of the hills in the afternoon hours, as this would place them in the shadow of the hills and therefore require that the FAC look into the sun while searching for them from the east. If the FAC was flying on the west side of the hills, he would be looking into a shadowed area making it difficult for him to observe any great detail below."*

The major use of terrain for cover, however, was in natural caves found in the limestone areas of Indochina (Fig. 26). Limestone occurs primarily in the region north of 17° N latitude, except for small outcrops in western Cambodia. In the limestone area east of Thakhek, the terrain is very rugged and deeply dissected. This is the area of STEEL TIGER and RP 2 where roads from North Vietnam go through Mu Gia Pass to Laos.

The extensive use of caves was noted in the COMMANDO HUNT III Report.[63/]

> *"Well stocked storage areas were essential to the shuttling procedures forced upon the enemy by interdiction attacks. Since there was no ground threat to his resupply operations in Laos, he developed extensive cave and underground storage areas and used elaborate techniques to camouflage his equipment and supplies.*
>
> *"A substantial AAA force was already in Laos when COMMANDO HUNT III began. Guns from the previous dry season had been stored in caves and were readily available."*

The limitations to operational tactics were minimal. They affected reconnaissance results to some degree but they were not very significant to strike except in certain cases.

The effects of adverse terrain features on tactical airlift were perhaps best described by Maj. Gen. Burl W. McLaughlin in his End of Tour Report:[64/]

> *"The contrasting terrain of South Vietnam, from the inundated paddies of the Mekong Delta to the rugged highlands of the central interior, presents a host of engineering problems that force compromise in design criteria. The lack of dry land in the Delta region necessitates extensive dredging before even the most austere airfield can be designed. Parking facilities are therefore extremely limited, and runway subgrades are inferior. BAC Lieu, Dong Tan, and Vinh Long are prime examples. At the other end of the topographic spectrum, mountainous terrain dictates the design of an airfield to an even greater degree, necessitating the location of over half of our II Corps airfields on ridge tops (Gia Nghia, Bu Krak) or in valleys (Dak Pek, Dalat Cam-Ly). Approach and lateral clearances are minimal because of congestive vehicular, helicopter, and pedestrian traffic."*

Reconnaissance

The irregular terrain found in Indochina created scale problems in the accomplishment of area reconnaissance.[65/] Scale was a function of the relationship between the focal length of the camera lens and the flight altitude of the aircraft. In areas of extreme relief, it was almost impossible to obtain constant scale photography. This photography was important for accurate measurement of enemy installations and to accurately locate important targets.

In many areas, particularly in Laos, LOCs and other lucrative targets were located in valleys. To fulfill scale requirements, aircraft using short focal length cameras, had to fly at altitudes above the valley floor that often placed them even with or below the tops of ridges. With AAA batteries located on the ridges, the enemy was able to fire on the aircraft from the sides or even from above.[66/]

In EC-47 operations, most of the problems attributed to natural phenomena were due to weather and terrain. Loss of some time in operating areas or total loss of some missions were wholly based on weather. However, terrain and shoreline effects from the Vietnamese coastline did interfere with effectiveness of ARDF equipment.[67/]

Strike

Rugged terrain limited the flexibility of run-in headings on strike missions. In addition, it restricted drop altitudes and angles because of the limitations of pullout.[68/] According to two F-4C crew members of the 366th Tactical Fighter Wing:[69/]

> *"[Karst] eliminates one of our automatic bombing modes...because it is not a flat enough surface to get a return...that is accurate enough for our needs. There is a problem in trying to get a bomb in at an optimum angle to give us the greatest damage because of pull-ups. There may be a cliff right behind the target. The ideal way of cutting a road line is to cross it, but not if there is a 55-foot cliff standing right up next to it...."*

PAVE WAY weapons (guided general purpose bombs) were used to provide accurate launch capability against caves. In a typical mission flown on 1 September 1969, Banyan Flight, three F-4Ds of the 433d Tactical Fighter Squadron (TFS) at Ubon, Thailand, released six weapons at four separate targets in Laos including a bridge and three different caves. Direct hits were scored and destroyed all three cave mouths.[70/]

PAVE WAYs also proved their worth against cave positions during a rescue mission at Ban Phanop. Located at the bottom of a river valley in northeastern Laos, the survivor was in proximity to a massive limestone outcropping which contained several caves protecting 57-mm, 37-mm, and 23-mm guns. In two days, 20 PAVE WAYs were launched against the gun positions protected by the nearly impenetrable karst. This tactic was successful in aiding the SAR mission by silencing the gun positions.[71/]

Another feature of the terrain which must be considered, particularly as it affects strike aircraft, is the waterway system of Indochina. Waterways were used by the enemy LOCs, initially with sampans and pirogues, and later with floating drums and waterproof bags. Some of these rivers were located in the STEEL TIGER area where there were four major tributaries of the Mekong River. These rivers had many tributaries consisting of smaller rivers and streams making travel by waterway possible for many miles. The high water period was generally from July through October and the low water period occurred from January to early May. The waterways at low water, especially those within the enemy's infiltration corridor, were characterized by numerous rapids, rock outcrops, sandbars, and shallow depths. These hazards rendered many of the waterways unnavigable; however, others were navigable sectionally by pirogues. At high water, the depths were increased sufficiently to eliminate the low water hazards.[72/]

With the use of these rivers as flotation channels for barrels and bags, many improvements were made in the waterways by the enemy. New

[redacted]

channels were cut through sandbars and existing channels were deepened. Rocks, log-booms, and cables were used to channel supplies downstream,[73/] and in an effort to control the water level in some rivers, flood control dams were constructed. With the enemy making good use of the natural environment in this effort to move supplies, the USAF countermeasures were not always effective. PAVE WAYs were used against construction in rivers, but this action deepened the channels more. Attempts were made to use natural elements by blasting more sediment into the river to impede flow by natural deposition of materials at choke points. At this reporting period, efforts to halt the flow of supplies by floating drums and bags were not too successful. According to Maj. Walter Pokorny, 7AF, DITTD, rivers were mined with MK-36 magnetic mines. If the water were deeper than 20 feet, however, these mines were not effective. He pointed out, "You can't stop them, but you can slow them down and divert them."[74/] Terrain was not a factor in gunship operations except where it served as a potential shield.[75/]

Rescue

As far as rescue was concerned, terrain did have some effect. Locating downed crew members in rugged terrain was occasionally difficult. In the hours of darkness or low visibility, rescue helicopters were, for the most part, ineffective for rescue and recovery, especially in mountainous terrain. A number of factors entered into the problem, such as navigation to the search area, terrain avoidance, as in rugged

[redacted]

mountainous areas, the descent to a hover mode, positioning the rescue craft over the downed airman, and finally, the establishment of the hover not to exceed movement five to seven feet laterally nor altitude deviations of greater than five feet.[76/]

Some of the difficulties involved with SAR in rugged terrain are exemplified by this debriefing of a rescued pilot.[77/]

> *"As I was coming down right above the karst, I started holding down the right riser and steering the chute away from the top of the karst. The turn worked out successfully, as I got myself pointed in the right direction, but I did not have enough altitude to effectively steer far away. I saw that I was going to hit in the trees, so I discontinued steering, put my feet together, shielded my face, and prepared for a parachute landing fall or tree penetration. I went through the tops of the trees, and my chute hit the trees and hung up, causing a very gentle tree landing. I was six feet from the side of a karst face, and although I could not see the valley floor due to the dense foliage, I estimated it was 100 to 200 feet below me. There was also a ledge of karst about 25 feet below me."*

An Air America H-34 helicopter had followed the pilot into the valley. He attempted to rescue the downed airman, but his aircraft was not equipped with a tree penetrator and his rescue harness would not penetrate the trees. The rescued pilot said:[78/]

> *"At this time, the H-34 hovered in the valley, level with me, and I could see the door. It edged over toward me with a horse collar lowered until it was hanging even with me, but the karst prevented them from hovering directly over me and the cable hung up in the trees. They attempted to swing the collar like a pendulum over to me, but it was too light to swing. The H-34 tried unsuccessfully for about ten minutes to get the collar to me before*

a Jolly Green arrived in the valley. I yelled into the radio, asking the H-34 to move out and let the Jolly Green lower a penetrator. My wingman finally got the H-34 to pull out, and the Jolly Green moved in with a PJ on the hoist. The PJ was unable to get to me due to the trees and because the refueling probe of the helicopter forced it to remain too far from the karst face. I used my helmet and oxygen line as a lasso; the PJ grabbed it and reeled himself over to me. The PJ was sitting on two legs of the penetrator and was strapped in, with another strap ready to put around me. He lowered the third seat, but I was unsuccessful in getting on it. I felt secure enough from the strap under my arms and did not attempt to use the seat any more. The PJ was on the radio and called to have us raised a foot or two so that he could cut the shroud lines and back pack which were still connected to me. It took ten minutes to cut all 28 lines. He then swung us away from the tree and we banged into another tree before being hoisted up to the chopper."

Extracting survivors from valleys created the same problems for rescue as noted in reconnaissance--the possibility of flying beneath the position of enemy guns.

Use of Terrain for Interdiction

In many cases, terrain was used to advantage by the USAF, particularly in the interdiction campaign in Laos. As noted in the COMMANDO HUNT III Report:[79/]

"The two primary tactics used against LOCs were emplacement of area denial munitions packages and the cutting or blocking of roads by bombing. Munitions packages were emplaced on the LOCs leading from the entrance passes, Mu Gia and Ban Karai, into Laos. The objective was to block traffic from moving into the Lao LOC system for as long as possible. A special F-4 operation, Night Owl, dropped flares and

CBU bomblets on the LOCs in the Mu Gia area to discourage enemy road repair crews from clearing the munitions packages....

"There were points on some routes which were difficult to repair and not easily bypassed. These points were cratered with strings of general purpose bombs or with precision ordnance such as the 2,000 pound laser-guided PAVE WAY bomb. PAVE WAYs were also used to create landslides and to cut fords, particularly in the Ban Laboy area south of Ban Karai Pass."

The NVA created a massive network of roads leading from North Vietnam through Laos for the movement of supplies into South Vietnam. To achieve the goals of the interdiction campaign in STEEL TIGER, it was necessary to select feasible interdiction points (IDPs) for the cutting of roads and the emplacement of munitions packages. This aim required a thorough knowledge of terrain and soils. As stated by Maj. Leonard H. Perroots of 7AF, DITS,[80/] "We need terrain studies and geography to anticipate his [the enemy's] actions in order to take counteractions." Geographic factors proved very important in the selection of both ordnance and IDPs.[81/]

Interdiction points were initially selected from aerial photography. Two criteria were generally used. Roads running along the sides of mountains made good IDPs as well as places which could not be easily bypassed.[82/] The final selection of the IDPs was made in consultation with FACs who were most familiar with the terrain itself.[83/] Roads on sides of mountains were cut by creating slides (Fig. 27). Munitions packages were emplaced where bypasses were difficult to construct. These packages consisted of:[84/]

[redacted]

Landslide traps bulldozer on Laotian mountain road.

FIGURE 27

[redacted]

Munitions	Description
Cutting Ordnance	PAVE WAY laser-guided or general purpose bombs fuzed for cratering of roads and fords.
MK 36 Landmines	General Purpose 500-lb. bombs fitted with retarding fins and a magnetic antivehicle fuze.
CBU-39 Gravel	Canister dispensed, camouflage, antipersonnel mines.
CBU-24/29	Antipersonnel bomblets set to detonate on impact and at random intervals until 30 minutes after impact.
CBU 42	Wide area antipersonnel mines (WAAPM), a bomblet, which armed after impact, deployed trip wires, and detonated if disturbed.

An air presence was maintained over the package area, as cuts and packages delayed vehicle movements by creating choke points which increased the probability of killing trucks. Enemy persistence and improved enemy efficiency in road construction and repair, however, made it necessary to maintain a continuous IDP bombing effort.

Weather was also used as an aid in interdiction. When corduroy roads indicated low spots, ordnance was delivered to carve these sections into deep muddy spots. This was really an attempt to aggravate the natural actions of the wet monsoon season as enemy problems were compounded twenty-fold in the rainy season.[85/] It also led to the selection of wet-weather IDPs. PAVE WAYs were expended on fords, allowing high water to completely wash the fords away.[86/]

Summarizing, terrain acted as a deterrent and an ally in the prosecution of the Southeast Asia conflict. As cover and by its extreme ruggedness in certain areas, it counteracted USAF efforts. Principally, however, because of the unique qualities of terrain, it aided greatly in the interdiction campaign.

CHAPTER III

EFFECTS OF AIR OPERATIONS ON THE ENVIRONMENT

Man tends to alter the face of the earth in diverse ways through the process of spatially organizing his society. There is a direct relationship between the degree of alteration and the technological level of the society involved. Although more primitive groups may make little impact, more sophisticated societies make massive changes. Ecosystems are delicately balanced. Disruption of one variable tends to upset this balance, so that changes to one facet bring about changes to others. This is perhaps best exemplified by slash-and-burn agriculture.

Slash-and-burn agriculture involves the clearing of an area by cutting down brush and trees, removing a portion of the bark on larger trees, and burning over the plot. The whole procedure is aimed toward destroying the existent vegetation and adding nutrient to the soil through the medium of wood ash. The removal of the vegetation changes the ecosystem of the small plot of land. Forest species of fauna retreat into surrounding areas. Although the precipitation will not be changed, the temperature regime will. The air in the forest tends to be cooler because radiation from the sun does not penetrate the canopy. Changes will take place in the soil. Laterization becomes more evident because soil is exposed to the leaching effects of rain and the drying effects of wind. In essence, a new ecosystem has been formed.

After the cultivation cycle is over, due to deterioration of soil fertility, the field is abandoned. If the plot is burned annually, trees will not be reestablished, and savanna will become the significant vegetation. If the field goes unburned it will, over a long period of time, go through a normal succession until secondary forest is restored. Since many of the forests in Indochina may be classified as secondary forests indicates not only that man has been active there for a long time, but also that he has brought about a massive transformation of the natural landscape.

One cannot assess the full cycle of permanent settlements so easily, because these areas are not permitted to return to a natural state. There are, however, the same kinds of effects to climate and soils.

In essence, the application of massive firepower by airpower in addition to the use of herbicides has intensified, magnified, and accelerated changes to the ecosystems of Indochina. Since there is great concern for natural environment today, it is important to point out not only the effects which were observed, but the attention which was given to these effects by those in command of the operations. There is no question that the weapons delivered by air have saved Allied lives. In the military situation, this was the primary consideration.

The main effect of air operations on the environment has been the massive removal of vegetation by use of herbicides and bombs. These weapons work in two different ways. Herbicides, generally, remove foliage from trees. Trees were killed in mangrove areas and in forests where chemicals were applied more than once. In any case, herbicides did not expose the soil, they only changed the character of the vegetation. Fred H. Tschirley, USDA Ecologist, performed a study for the Herbicide Policy Review Committee in 1968. His conclusions were:[1/]

> *"If my assignment here had been simply to determine if the defoliation program had an ecologic effect, the answer would have been a simple 'yes,' and a trip to the country would not have been necessary. But to assess the magnitude of the ecologic effect is an entirely different matter.*
>
> *"One must realize that biologic populations, even those remote from man, are dynamic. Seasonal changes, violent weather events, fire, birth maturation, senescence, and death cause a continuing ecologic flux. Normally, the ecologic flux operates within narrow limits in a climax community. It is only catastrophic events that cause an extreme ecologic shift and reduce the community to a lower [ecologic] stage.*
>
> *"That defoliation has caused an ecologic change is undeniable. I do not feel the change is irreversible, but recovery may take a long time.*
>
> *"The mangrove type is killed with a single treatment. Regeneration of the mangrove forest to its original condition is estimated to require about 20 years.*
>
> *"A single treatment on semideciduous forest would cause an inconsequential ecologic change. Repeated treatments will result in domination of many sites by bamboo. Presence of dense bamboo will then retard regeneration of the forest. The time scale for regeneration of semideciduous forest is unknown. Available information is so scanty that a prediction would have no validity and certainly no real meaning. The time required for regeneration to its original condition would certainly be longer than was estimated for mangrove.*
>
> *"The effect of defoliation on animals does not appear to have been extreme. But I hasten to add that I know far*

less about animals than about plants. The fish catch has been increasing at about the same rate as [the] number of fishermen, which surprised and pleased me. Actual data were not available for population trends of other forms of animal life. Large mammals have been seen recently in War Zones C and D, the areas of greatest defoliation activity. Included were tiger, monkey, elephant, and deer."

More significant changes to the environment were noted in those areas where massive high explosive ordnance was used. Tschirley wrote:[2]

"Under natural conditions laterization is a long term process. The process is speeded up when soil is exposed to direct solar radiation and wind. I do not find it reasonable that the defoliation program in Vietnam would hasten the laterization process significantly because bare soil does not result from defoliation. It is possible, however, that laterization will be speeded up around base and special forces camps where the soil is maintained free of vegetation."

High explosive bombs exposed the soil in the same way as clearing of land around base camps (Fig. 28).

The ultimate effects of the Southeast Asia conflict on the ecosystem will not be known for many years. Regeneration of the forests should come with time. Success of air operations, however, has to be measured in terms of military and political goals, not physical changes to the environment.

SECRET

Extensive bombing strips vegetation
near Ban Karai Pass

FIGURE 28

SECRET

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APPENDIX I

GEOGRAPHIC, PHYSIOGRAPHIC, AND ECOLOGICAL TERMINOLOGY

ALLUVIAL PLAIN	A level or gently sloping flat or slightly undulating land surface resulting from extensive deposits of mud, silt, etc., by running water.
ALLUVIUM	Sediment deposited by flowing water on a flood plain or delta.
DELTA	The deposit of alluvium made by a stream flowing into a body of standing water.
DISTRIBUTARY	One of several channels into which a stream tends to divide when flowing over a delta surface.
ECOLOGY	A branch of science concerned with the interaction of organisms with their environment.
ECOSYSTEM	An ecological community together with its environment, considered as an interacting unit.
HARDPAN	A layer of hard subsoil or clay.
KARST	Type of topography formed by the action of water on limestone. Characteristically, it contains caves, underground rivers, sink holes, solution basins, and grotesque outcroppings.
LATERIZATION	Process which occurs in tropical soils. When soil is exposed to sun, wind, and rain, percolating water, moving through the soil, leaches silica out leaving oxides of aluminum and iron. Hardpan forms and soil becomes relatively infertile.
MANGROVE	Generic term for a large variety of plants which grow in tidal flats and marshes. They can tolerate both fresh and salt water.

MASSIF	The dominant, central mass of a mountain ridge, more or less defined by lengthwise or crosswise valleys; a large block of the crust of the earth which is isolated by boundary faults and has shifted as a whole.
MEANDER	Large loops and bends in a river created as the stream wanders through its valley. If the earth's crust is subsequently uplifted, meanders can become entrenched thereby preventing the river from wandering outside its established bed.
MONSOON FOREST	Deciduous forest found in tropical climates where the rainfall averages 60 to 80 inches per annum with a definite wet and dry season. Trees are leafless during the dry season.
PRIMARY FOREST	Virgin forest unaltered by man.
RAIN FOREST	Evergreen forest found in regions where the annual precipitation exceeds 80 inches and is evenly distributed throughout the year.
SAVANNA	Grassland interspersed with trees which has a long, very dry season alternating with a wet season, but no winter cold. Some savanna may be caused by annual burning which retards the growth of forest tree species.
SECONDARY FOREST	Forest which grows after primary forest has been removed by cutting or burning. Almost all forest presently found in Southeast Asia is secondary forest.
SLASH-AND-BURN AGRICULTURE	A clearing, usually on a hilltop or hillside, is made by cutting down small trees and underbrush and slashing off the limbs of larger trees. The trees are girdled so they will die. When the trees, brush, and limbs are dry enough the clearing is set afire. The ashes serve as fertilizer, and the plot is tilled until the land becomes overworked and unproductive. The process is then repeated elsewhere. Sometimes called "shifting agriculture."
TRIBUTARY STREAM	A stream which joins with other similar streams to form a trunk stream, or river.

GLOSSARY

AAA	Antiaircraft Artillery
AD	Air Division
ADVON	Advanced Echelon
AGL	Above Ground Level
API	Armor Piercing Incendiary (Ammunition)
ARDF	Airborne Radio Direction Finding
ARRS	Aerospace Rescue and Recovery Squadron
BDA	Bomb Damage Assessment
CBU	Cluster Bomb Unit
CEP	Circular Error Probable
CINCPAC	Commander-in-Chief, Pacific Command
COMUSMACV	Commander, United States Military Assistance Command, Vietnam
CTZ	Corps Tactical Zone.
DMZ	Demilitarized Zone
EEI	Essential Elements of Information
FAC	Forward Air Controller
FOLA	Forward Operating Location A
FPS	Feet Per Second
HEI	High Explosive Incendiary
IDP	Interdiction Point
IR	Infrared
JCS	Joint Chiefs of Staff
JUSPAO	Joint United States Public Affairs Office
LOC	Line of Communications
MACV	Military Assistance Command, Vietnam
mm	millimeter
NOD	Night Observation Device
NVA	North Vietnamese Army
NVN	North Vietnam; North Vietnamese
OJT	On-the-Job Training

PACAF	Pacific Air Forces
PCT	Percent
PI	Photo Interpreter
PJ	Pararescueman
PW	Prisoner of War
Recon	Reconnaissance
RP	Route Package
RVN	Republic of Vietnam
SAC	Strategic Air Command
SAG	Special Activities Group
SAR	Search and Rescue
SEA	Southeast Asia
SLAR	Side-Looking Airborne Radar
SOS	Special Operations Squadron
SVN	South Vietnam
TASS	Tactical Air Support Squadron
TFS	Tactical Fighter Squadron
TFW	Tactical Fighter Wing
TRW	Tactical Reconnaissance Wing
USAID	United States Agency for International Development
USDA	United States Department of the Army
USMACV	United States Military Assistance Command, Vietnam
VC	Viet Cong
VR	Visual Reconnaissance
WAAPM	Wide Area Antipersonnel Mine
WAIS	Weekly Air Intelligence Summary